10ième Congrès national sur la Gestion des déchets ◆ 10th Canadian Waste Management Conference

COMPTES RENDUS ◆ PROCEEDINGS

Les 25, 26 et 27 octobre 1988
(Winnipeg) Manitoba

25-27 October, 1988
Winnipeg, Manitoba

Environnement Canada Environment Canada

Canada

PROCEEDINGS | **COMPTES RENDUS**

10th CANADIAN WASTE MANAGEMENT CONFERENCE

10ième CONGRÈS NATIONAL SUR LA GESTION DES DÉCHETS

October 25-27, 1988
Westin Hotel
Winnipeg, Manitoba

Le 25-27 octobre 1988
Hôtel Westin
Winnipeg, Manitoba

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© Minister of Supply and Services Canada 1988
Cat. No. E40-11/3-1988
ISBN 0-662-56417-0
BEAUREGARD PRINTERS

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N° de cat. E40-11/3-1988
ISBN 0-662-56417-0
IMPRIMEURS BEAUREGARD

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"CCREM PROGRAMS AND INITIATIVES"

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Paper unavailable at time of printing

U.S. EPA LANDFILL STANDARDS, RESTRICTIONS AND TREATMENT REQUIREMENTS

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THE DANISH APPROACH : A MODEL FOR OTHER NATIONS' WASTE MANAGEMENT POLICIES

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1 Introduction

Denmark is one of the smallest countries in Western Europe, only counting for about 5.6 million inhabitants and covering an area of about 300 x 350 kilometers. It is at the same time a country depending on agriculture and industry, and its living standard must be regarded as one of the highest in Europe.

Denmark has a long tradition with regard to environmental protection policies - and Denmark has obtained a leading position in Europe concerning the environmental standards. The Danish approach can serve as a model for other nations' waste management policies.

In the following, two main elements of the Danish environmental policy will be described: the central system for the treatment og hazardous wastes and those measurements taken in order to implement the prevention principle as means of our environmental policy.

2 Administration and legislation

Denmark is divided into 16 counties, consisting of 273 municipalities. The Ministry of Environment is the highest administrative authority within the field of environmental protection, and the National Agency of Environmental Protection (NAEP) serves as its adviser and substitute.

According to the general decentralization principle in Danish principle in Danish policies, the local authorities in the municipalities or counties will take charge of the duties pursuant to the legislation on the protection of the environment. They have to permit or license any kind of activities according to the existing rules and laws, f.x. the authorization and permission for facilities, the administration and establishment of the local waste collection-, receival- and treatment system as well as the exemptions and the control system. The regional and national authorities are serving as appeal instances; complaints against decisions made by the NAEP will be negotiated by a special Environmental Appeal Board, which is an independant board not being subject to instructions issued by the Minister of the Environment.

The environmental legislation is mainly based on socalled outline or framework act empowering the Minister of the Environment to stipulate detailed rules and to issue regulations within the frame of the acts. Two of the most important acts are the act on "Disposal of Oil and Chemical Waste" from 1972 and the act on "Protection of the Environment" from 1973 . Both laws have been revised since then, inter alia by introducing "Cleaner Technologies", as it will be shown later.

Major changes in environmental strategies can only be fulfilled and implemented by revising the existing laws. The legislative system is one of the key elements of environmental policies !

3 The "Kommune Kemi" system

The Danish system - often called the "Kommune Kemi" system - has its background in a national legislation, but the control, collection and transport system are under the responsibility of the local authorities. Only the central transfer stations and the central treatment plant and the connected transportation system can be regarded as central elements: this is conform to the above named decentralization principle in the Danish environmental legislation.

3.1 The act on "Disposal of oil and chemical wastes"

The cited act gives the Minister of the Environment the administrative authority to issue regulations pertaining oily and chemical waste. Such provisions are brought into effect by different "regulations" set forth by the Ministry of the Environment.

The objectives of this act and of the regulations are to prevent and combat pollution caused by oil and chemical waste. Each type of storage, transport or disposal, including burning or final deposition of chemical waste as well from industry as from households is covered by the act.

3.1.1 Definition of chemical waste

It is not possible to give an exact definition of the term "chemiccal waste". While some countries in their legislation enumerate several hundreds of chemical compounds which occurrence in wastes will classify them as toxic, dangerous, hazardous or chemical waste, Denmark has chosen to establish a list of about 50 types of wastes, and no concentration ranges are given. This list, which is subject to permanent extension, is divided into 5 main groups: 1) Animal and vegetable fats, 2) Organic compounds containing halogen, 3) Organic halogen-free compounds, 4) Inorganic compounds, 5) Other wastes.

The purpose of this definition is on the one hand to exclude any risk for the human and natural environment by an inappropriate treatment, and on the other hand to have a legislation being as flexible as possible with regard to new technological developments and knowledge.

In our view every classification of chemical wastes using concentration limits or quantities should be avoided when formulating regulations and guidelines. The delivery of chemical wastes to treatment or other controlled final disposal would be seriously affected by such definitions, as irresponsible waste generators might be tempted to dilute wastes or split them up in smaller quantities and thus make the efforts of the authorities worthless to fight the pollution resulting from inappropriate disposal of chemical waste.

Technology is not static, but dynamic, and an updating of the legislation from time to time is necessary. The NAEP set up a standing commitee with representatives from the chemical industry, the relevant organisations and local and central authorities to follow the industrial and technological progress and cosequently propose appropriate amendments and additions to the current legislation.

3.1.2 Responsibilities

Principally, a generator of hazardous waste is responsible for the declaration, notification and delivery of the wastes. If he uses subcontractors for the transport or if he has got a dispensation for the delivery, it is still his responsibility to take care of the treatment of the hazardous wastes according to the rules.

Furthermore, it is ruled that the waste generating enterprises are obliged report on their chemical waste to the local authorities. These reports must indicate whether the waste has been generated during the normal production process or by accident.

The local authorities will review the information and have to give instructions regarding the delivery of the oil and chemical waste. This will normally imply the delivery to a transfer station (see below) for further transport to the central treatment station. Exemptions may, however, be granted concerning the obligation to deliver waste to the treatment plant. If an enterprise does not wish to deliver waste to the intermunicipal transfer station, the local authority may grant an exemption, provided it is substantiated that the waste is disposed of in some other environmentally acceptable way, mainly recycling.

3.1.3 Trip-ticket system

Each waste producer must complete a manifest which gives information on the chemical waste including the type of waste, the mainn group according to the above named groups, the characteristics, the components, the process from which the waste is derived, the quantity and the mode of delivery. The manifest is a multiple copy form, which is used at three main points: the supplier (Waste producer), the waste transfer station and at the central treatment plant (Kommune kemi).

3.1.4 Collection and storage system

There are three general possibilities for the storage of the hazardous waste in Denmark: at the about 300 collection points (at least one in each of the 273 municipalities and 16 counties), at the 21 transfer stations and at the central treatment plant.

The collection points are used for the receipt of oily and chemical waste from households, and generally they are place near public plants such as municipal refuse dumps, storage yards, sewage treatment plants or similar installations in order to have personnel and control possibilities available.

The transfer stations are receiving oil and chemical wastes from industry and other sources. They are much bigger and more comprehensive than collection points.

Witout going into further details, it shall be mentioned that Kommunekemi's central treatment plant has the following receipt and storage sections: railway tank emptying section, drum emptying section, inorganic chemical waste section, waste oil section, receiving pit for other burnable wastes and container sites.

3.1.5 Transport system

There are two general transport situations for chemical wastes from industry : the transport of chemical wastes from the industrial generator to the transfer stations and the transport from those stations to the central treatment plant.

All transports are subject to special rules concerning vehicles, packaging, labelling, safety equipment and safety regulations. Many of the requirements and rules are given on the "chemical waste"-cards which must accompany the waste during transportation. Furthermore, a special guide called "Emergency measures in the event of accidents caused by dangerous substances on the ground" has been worked out by the NAEP in order to ensure a safe transport of hazardous waste.

The waste generator is responsible for the safe transportation of the waste from its place of origin to the transfer statio, and he remains in that resposibility even if the transport is carried out by a contractor.

However, some of the transfer stations have established collection services, for example on-site collection of chemical wastes (pick-up). This means that the collection of oily and chemical is taken over by the transfer station by using the station's own contractor. This transport service is normally free of charge for the waste generator, and it is paid by municipal tax money.

Consequently, there has been made an agreement with the Danish National Association of Local Authorities - the association of all municipalities - to establish pick-up services at all transfer stations.

3.1.6 Treatment system

The Kommune Kemi waste treatment plant is the central treatment plant for Denmark. It went into full operation in 1974, and it is sited a few hundred meters from a modest sized residential area in the town of Nyborg with about 18 000 inhabitants.

The treatment is based on conventional stepwise detoxification processes (oxidation of cyanides by a hypochlorite solution, reduction of chromate by iron-containing wastes and neutralization by lime). The heavy metals are precipitated as hydroxides and are removed by a filter press and deposed in a controlled landfill.

Filtercakes from the inorganic plant, slag, ashes and dusts from the two imcineration lines have to be disposed at Kommunekemi's controlled landfill, sited about 20 km from the treatment plant in a limestone area close by the coast of the Great Belt. The site covers an area of about 15 ha and is subject to all controll measurements according to environmental regulations. Before being disposed at the landfill all deliveries must be controlled by Kommunekemi's laboratory, which also is responsible for the control of the surface water and groundwater as well as the percolate at the site.

Kommunekemi's largest treatment section consists of two incinerator plants, where solid, liquid and pasty organic wastes can be incinerated. There is a combined loading hall with two rotary kilns connected to secondary combustion chambers. A major change in the incinerator system is presently under way.

There are also made great efforts to avoid the export of wastes to a saltmine in West Germany for final deposition because of unsufficient treatment possibilities in Denmark.

4 New trends in environmental policies

Denmark has obtained a leading position in Europe with concern to environmental protection : this is the result primarily of state activities which have led to the development of comprehensive administrative and legislative approaches within the last two decades.

But, often helped by the public opinion and increasing public awareness, it must be stated, that the state of environment is not as good as it should be. Old failures and the lack of sufficient environmental law and control measurements in the past, especially in the years with a rapidly growing industry, are causing enourmous technical and economic problems to-day, and new threats of unknown dimension can be foreseen. Examples could be the growing groundwater contamination, increasing heavy metals contamination, problems both with regard to air and water emissions, growing waste quantities and the lack or the impossibility of establishing waste treatment facilities. Furthermore, no one knows which new challenges the development of new materials, new alloys or new biological and chemical production processes and products will present !

But, on the other hand it also can be stated that there has occurred a change of mind. People are becoming more and more aware of the fact that it is totally inadequte to "clean up" or to react to problems without having a chance of solving them. It is not enough to deal with waste treatment technologies, with remedial action techniques or waste handling or abatement methods, with end-of-line solutions. The conclusion is that there is a strong need for a preventative policy, a cleaner technology policy, which tackles environmental problems before they occur. It is becoming clear that this is a much more encompassing environmental model, because it deals with the product cycle as a whole !

4.1 Cleaner technology - definition and means

There are many different definitions of the term "cleaner technology" - and these differences will always be an academic discussion, whether one emphasizes low- and non-waste technology, cleaner technology, less polluting technology or environmental technology, just to name some of the existing terms. In many cases the terms used and their connotations in the individual countries must be seen in the context of specific historical, administrative or judicial developments which hinder a more technical justified change or the adoption of the term in the administrative systems.

In the Danish context, cleaner technologies are those preventive approaches within the product life cycle - including raw materials, production processes, the products themselves and the spill ore waste products - which minimize the environmental load caused by the named activities. This definition excludes end-of-line solutions. Furthermore, the Danish consider the term "cleaner technology" as a dynamic one : no industrial process can be neutral to the environment, there will always be environmental implications. Therefore, all industrial efforts can only be optimized. That means that it always has to be the aim of environmental protection policies to make the product life cycle cleaner.

This can be achieved by the following four approaches:

1) Choice of alternative raw materials;
2) Development of new production processes or methods;
3) Development of new or alternative product designs;
4) Combinations of 1 - 3.

ad 1) It is a basic principle that those raw materials which contain fewer pollutants produce fewer environmentally polluting emissions. But also the choice of alternative materials with the same function in the production process or in the product will make a given production cleaner. These substitution processes can be divided into physical, quantitative or functional substitutions.

ad 2) The development of new production processes or methods is a very important part of a cleaner technology conceptualization. Special attention has to be paid to the fact that there are not only physical, chemical or other machinery oriented possibilities for the development of new production processes or methods, but also e.g. organizational ones such as the introduction of new wage systems.

ad 3) New or alternative product designs include new approaches with regard to material, function and construction

ad 4) In many cases there will be a combination of the above named principles because of the interdependence of raw materials, production processes and product design.

4.2 Laws and experiences

There are basically two Danish laws which gave the background for the administrative experiences which led to the implementation of the new development program for cleaner technologies in Denmark. They are:

4.2.1 The "Environmental Investment Act"

The revised "Environmental Investment Act" from 1980-1986 which succeeded two former acts from 1975 and 1978, provides the possibility for governmental subsidization of "new or less polluting technology" in order

- to create a stimulus for starting up "cleaner technology" projects and
- to enable the environmental administration to have influence on future choices of technology within industry and
- to direct the technological development to focus upon environmentally beneficial goals.

The "Environmental Investment Act" did not result in the number of projects which was hoped for. Support was granted to only 18 projects out of 70 applications. One of the reasons may have been the limited prerequisites for becoming subsidized, but mostly it must be stated that the applications did not fulfill the requirement of introducing new technology. The intentions of the act, regarding the stimulation of cleaner technologies, were not fulfilled.

4.2.2 The "Act on Recycling"

The first "Act on Recycling" of 1984, included all waste types and provided the possibility of subsidizing projects for the development of "less polluting technology". This term was not defined more clearly, but practically, the traditional ways of limiting environmental pollution (end-of-line approaches) were specifically excluded in order to promote the development of new, integrated, cleaner technologies.

In the course of the first 15 months of the act (oct. 84 - dec. 86), subsidies in the amount of about 13 million Danish Kroner were granted on 15 projects within a lot of different branches. But also in the case of this act, it had to be stated, that the interest of industry for developing cleaner technologies with the help of subsidies was rather limited.

4.2.3 Experiences with the "Environmental investment Act" and the "Act on Recycling"

On the basis of these two laws, the following conclusions with regard to a cleaner technology policy can be drawn:

1) The introduction of programmes for the implementation of cleaner technologies is, to a very high degree, dependent on information activities which have to be directed towards specific industries or target groups, especially the smaller ones.

2)It must be emphasized that cleaner technology also encompasses changes of input raw materials as well as changes of product designs.

3) The willingness of industry to take risks, with regard to unproven cleaner technologies, is very limited.

4) New and lower emission standards and other environmental regulations can enforce the development and implementation of cleaner technologies.

5) There must be a high percentage of subsidy for a given project in order to reach a satisfying participation by industry.

6) It is apparent that the conceptualization of cleaner technologies is very complex, and that the development of new product cycles, processes and products takes a long time.

7) the promotion of cleaner technology programmes makes an active participation of the governmental administrative system inevitable.

4.3 The "Cleaner Technology Development Program"

Political developments in Denmark, increasing public awareness on environmental problems and the need for environmentally based technological developments forced the Danish Minister of the Environment to start a new, cleaner technology development, program for the years 1987 - 1989. This program is supplying the cleaner technology part under the above discussed "Act on Recycling".

4.3.1 Goals of the "Cleaner Technology Development Program"

The program is defined as a development program which shall generate, develop and test experiences in a limited number of industries in order to avoid unspecified actions and to ensure a coordinated policy.

The specific goals of this program are:

- to collect and systematize knowledge on cleaner technologies
- to define the barriers for a better use of cleaner technologies
- to inform industries and the public in a better way on the possibilities and the consequences of the utilization of cleaner technologies
- to generate a better basis for a dynamic revision of the NAEP's (National Agency of Environmental Protection) instructions to both industries and local authorities
- to obtain knowledge of the best means to improve the implementation of cleaner technologies
- to start research activities in or to obtain better experiences with the industrial implementation of cleaner technologies and
- to coordinate and make the cleaner technology policy more effective.

4.3.2 Structure and elements of the "Cleaner Technology Development Program"

The new development program consists of two main emphases:

a) to create and spread knowledge on cleaner technologies

b) to implement cleaner technologies within Danish industries

Industries, as well as the public, have a great knowledge concerning raw materials, processes and products - but this knowledge is not gathered or utilized in a systematich or priority-based way. Therefore, there is a need for the :

- development of methods like production processanalyses, input-output functions or models for an evaluation of production cycles from an environmental point of view;
- establishment of a data- and information-system which includes the development of formats and soft- and hardware systems;
- transformation and adoption of national and international knowledge to industry and administration

The other basic structural principle of the new "Cleaner Technology Development Program" is the implementation of cleaner technologies within Danish industries. This must become effective by an active decision making process that includes the public with its different possibilities of approval.
The new program presently consists of the following nine elements:

4.3.2.1 Collection and transformation of knowledge - natinal and international

4.3.2.2 Development and establishment of a data- and information system within a data-based network

4.3.2.3 Branch/industry related research

4.3.2.4 Technology based research

4.3.2.5 R&D- projects

4.3.2.6 Demonstration projects (full size scala)

4.3.2.7 Investment subsidies

4.3.2.8 Information and education services

4.3.2.9 Consulting system

4.3.3 Status

The financial support for this new program - 5o million Danish Kroner for a 3-year period - were granted on February 18th, 1987. Consequently, the NAEP had prepared the program according to the above mentioned structure and elements. Three main industries were chosen :

- metal treating industries
- wood/furniture industry
- food industry

The program is also directed towards other specific environmental problems such as mercury or heavy metal problems.

The fore-mentioned branches and the specific problems were also chosen as test-cases for the stablishment of a data-base on cleaner technologies.

The NAEP has chosen an active involvement of a special cleaner technology working group within the office of Recycling and Cleaner Technology, and it must be stated, that this working principle has led to good industrial participation. In the first 1 1/2 year of its existence, about 45 projects for about 35 million Danish Kroner were started - sometimes in combination with other technology-oriented Danish development programs from other ministeries.

4.3.4 Preliminary conclusions of the "Cleaner Technology Development Program"

a) The branch-related procedure ensures a high degree of coordination and helps both administration and industry

b) It is important that the administrative system plays an active role in order to promote cleaner technologies.

c) This implies a great need for collecting and gathering information and knowledge, eg. by being on the "spot", visiting conferences, seminars etc.

d) There is a need for coordination - both inside the administrative sytem and outside, eg. to other authorities or research programs.

e) The possibilities for introducing cleaner technologies are highly dependent on the legal framework and upon the local authorities' procurement of environmental laws.

f) It is necessary to define precise goals, target groups, approaches and steps in order to coordinate and fulfill the policies of such a program.

g) Industry is very often only willing to fulfill the minimum requirements with regard to existing or probable standards. This is one of the reasons for technological conservatism

SOLID WASTE MANAGEMENT PRACTICES
IN THE SOVIET UNION

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Solid waste management practices in the Soviet Union are similar in nature to those in North America. Landfill is the primary method of waste disposal. There is concern about the environmental effects of landfilling. In addition, there is opposition to siting of new sites near urban areas as well as in the rural parts of the country. Alternatives to landfill are being developed. Recycling, composting, and energy recovery are the alternatives that are promoted.

In June 1988, a delegation of 28 U.S. and Canadian members met with solid waste management officials in three cities in the Soviet Union. This paper is based on discussions with these officals and observations of their facilities. Leningrad, Minsk, and Moscow were the three cities visited. The Ministry of Housing and Municipal Economy was the delegation sponsor in the Soviet Union. People-to-People International, a U.S. based organization, coordinated the visit with the Ministry.

GOVERNMENT POLICY

Solid waste management practices appear to be based on decisions at the local level that are made in conjunction with the appropriate department in each republic. Technical assistance on these practices are provided by departments at the national level. In the areas of energy recovery, composting, and landfill the primary source of technical assistance is the U.S.S.R. Academy of Municipal Economy. Other departments have jurisdiction over other areas, such as recycling.

An example of the development of a disposal facility is the composting plant that was built in Minsk. This facility was a joint effort of the U.S.S.R. Academy of Municipal Economy and the Ministry of Municipal Economy of the Byelorussia Soviet Socialist Republic (SSR). Use of compost from the facility at state farms in the Minsk area also was coordinated with agricultural departments at several government levels.

Environmental regulation for disposal practices was primarily the responsibility of the departments that managed the facilities. Concern that these departments in all areas of the economy (e.g., industrial manufacturing) had failed to protect the environment in pursuing their primary objectives (e.g., steel production, waste disposal) led to the formation (1987) of a new environmental protection agency. This agency - U.S.S.R. State Committee for Environmental Control (U.S.S.R. Goskompriroda) - is responsible for environmental protection and the use of natural resources. Among the Committee's main tasks are the issuance of permits for landfills. In addition, the Committee is responsible for emissions from combustion facilities, including energy recovery plants. Regulation of the contaminants in compost is another task of the Committee.

WASTE CHARACTERISTICS

An understanding of the characteristics (generation rate and composition) of the solid waste stream in the Soviet Union is important to appreciate the waste management practices used in the U.S.S.R.
Average residential waste generation in Soviet cities was reported to be 0.22 tons (200 kilograms) per person per year. By comparison, in the United States, annual residential waste generation ranges from 0.47 to 0.53 tons (430 to 480 kilograms) per person. Several reasons exist for these differences in waste generation. One is the lower availability of packaged consumer products, and products in general. A second reason is that almost all residents in the cities visited live in apartment buildings, which minimizes the amount of yard waste discarded. Also the northern location of all three cities means a shorter growing season, than is typical of cities in the United States, which further reduces yard waste.

A comparison of solid waste from the Soviet Union and the United States shows two areas of significant difference (see Exhibit 1). One is paper and paper products, and the other is organics, specifically food waste. Actual sampling data from Minsk reported paper waste to be 23.6 percent of solid waste, while typical refuse in the United States contains 37.1 percent paper and paper products. Nationwide Soviet Union data indicates that paper discards can range from 20 to 36 percent of solid waste. In 1986, food waste in the Soviet Union ranged from 23 to 37 percent of the waste stream, whereas in the United States food wastes accounted for about 8 percent of solid waste.

The high percentage of food in the waste stream is due to several reasons. One, as mentioned previously, there is less packaged consumer products, including food, than in the United States. This means the by-products of food preparation, such as pits, peels, bones, are in the residential waste stream rather than packaging materials. In addition, although there are food waste recycling programs throughout the country, between 30 to 60 percent enters the residential waste stream. The food waste that is discarded is the percentage shown in Exhibit 1. Unlike the United States, Soviet residences lack garbage disposals, which means discarded food becomes solid waste rather than sewage.

SOLID WASTE MANAGEMENT PRACTICES

In each of the three cities visited, recycling and landfill systems were in operation. There were also resource recovery facilities (either composting or energy recovery) in the cities. The decision on whether to use composting or energy recovery appeared to be primarily a local decision. Composting was used in communities where there was a demand for the product, whereas energy recovery systems were selected in areas in which the facility could complement the district heating system. Landfill was an important part of the waste management system in all three cities. There are plans, however, to minimize the role of landfill in Leningrad and Minsk, the two cities with composting plants.

Recycling

Newspaper, corrugated, textiles, and food waste were the materials recovered by the recycling programs. Residents must deliver the first three materials

EXHIBIT 1

COMPARISON OF WASTE COMPOSITION IN THE SOVIET UNION AND THE UNITED STATES

	Soviet Union				
		National Average(2)		United States(3)	
Material Categories	Minsk(1)	1986	2000	1984	2000
Paper and Paper Products	23.6	20-36	22-37	37.1	41.0
Plastics	3.4	2-4	3-6	7.2	9.8
Rubber, Leather, Textiles	5.6	4-8	5-9	4.6	4.6
Wood	3.4	2-3	2-3	3.8	3.8
Organics	46.5	23-37	22-32	26.0	22.1
Food Waste	(33.1)	(23-37)	(22-32)	(8.1)	(6.8)
Yard Waste	(13.4)	-*	-*	(17.9)	(15.3)
Subtotal - Organics	82.5	51-88	55-87	78.7	81.3
Glass	4.2	5-7	5-7	9.7	7.6
Metals	5.2	2-3	3-4	9.6	9.0
Ferrous	-	(2)	(3)	(8.3)	(7.1)
Non Ferrous	-	(1)	(1)	(1.3)	(1.9)
Miscellaneous	8.1	8-28	8-24	1.9	2.1
Subtotal - Inorganics	17.5	15-38	16-35	21.2	18.7
TOTAL	100.0	-	-	100.0	100.0

(1) Ministry of Municipal Economy of the Byelorussia Soviet Socialist Republic.

(2) U.S.S.R. Academy of Municipal Economy.

(3) Franklin Associates, Ltd. "Characterization of Municipal Solid Waste in the United States, 1960 to 2000" U.S. Environmental Protection Agency; Washington, D.C. 1986.

* Yard waste is included within miscellaneous.

to a colection center; whereas, food waste is collected separately from other household wastes.

The recycling stations are run on a modified buy-back center principle. Participants receive credit that allows them to buy items that would be difficult to obtain othewise. For paper products, participants receive credit that enables them to purchase books. A purchase credit is received after delivery of 110 pounds (50 kilogram) of newspaper or corrugated. A credit for the purchase of new clothes is received when 220 pounds (100 kilogram) of textiles have been delivered to a station. Participation in the recycling program, which is in operation nationwide, is voluntary.

A reported 2.2 million tons (2 million metric tons) of paper products and textiles are recovered for recycling on an annual basis in the Soviet Union. Moscow, with a population of 9 million, recycles the largest amount of discards. Between 5 and 8 percent of the recovered recyclables were obtained in Moscow.

Residents are supposed to separate food waste from other household discards. In Moscow, a program has been initiated that enables residents to place their food waste in a paper bag. This bag can be discarded in the same refuse chute as other household waste. Food waste bags are separated from the other refuse by the person responsible for placing carts at the bottom of the waste chutes. Residents in other cities store their food waste in buckets, which must be taken to the basement for emptying into a collection container. Containers for food waste, along with other refuse, are collected daily. The food waste is taken to state farms near the cities. After cooking, the food is fed to pigs. Concern about transportation costs, in Leningrad, has lead to an investigation into pelletizing food waste as a way to reduce the expense of hauling.

On an annual average basis, almost 62 pounds (28 kilograms) per person of food waste are collected in the cities. An additional 101 to 163 pounds (46 to 74 kilograms) per person is added to the household waste stream.

Composting

Mechanical composting systems for unsorted municipal solid waste were in operation in two of the cities visited - Leningrad and Minsk. Six additional composting facilities were reported to be operating in the country. In addition, in Leningrad there was a trial program to recover decomposed waste (compost) from an old section of a landfill.

The Leningrad mechanical composting plant has the capability to process 25 percent (220,000 tons per year - TPY, or 200,000 metric tons - MTPY) of the city's waste stream. When the facility was built in 1970, it had a capacity of 88,000 TPY (80,000 MTPY). The composting plant was expanded in 1982 to its current capacity. Currently, there are plans to build two additional composting facilities. These plants, which are scheduled to be operational by the mid-1990s are planned to process all of Leningrad's municipal waste stream. Demand for compost by the state farms near the city was the primary factor influencing the decision to build additional facilities.

At the existing plant, municipal waste is delivered to the plant and unloaded into a storage pit. Refuse is conveyed to the digester, which is a cylindrical tube that rotates continuously at a slow rate. After two days, the material exits the digester drum. Compost is separated from the other materials in a trommel. The compost is stored in the open until there is a need for it about 6,100 tons (5,500 metric tons). Ferrous and non-ferrous metals are recovered annually from the non-compost rejects. The remainder of the rejects were reported to be fed to a pyrolysis plant. The pyrolysis plant has three outputs. One is a char (pyro-carbon) that can be used in metallurgical processes, a combustible gas for use internally in the plant, and a tar/pitch suitable for use in road construction.

Almost 159,000 tons (144,000 metric tons) of compost are produced annually at the Leningrad plant. The majority of the compost is allowed to cure (6 months) and is used on the agricultural land of the state farms. A portion of uncurred compost also is used in the early Spring as a sub-soil in greenhouses on the state farms. The heat of decomposition aids in plant germination. An increased yield for cucumbers of 25 percent was reported in Minsk by the Ministry of Municipal Economy of the Byelorussia SSR. In addition, this "bio-fuel" provides a buffer between the ground and the plant growing soil. Typically, two vegetable crops are grown in the greenhouses in a growing season.

The composting facility in Minsk has the capability to process 25 percent, or 88,000 TPY (80,000 MTPY) of the city's waste stream. The balance of the city's waste is taken to landfill. There are plans to expand the plant's capacity to 220,000 TPY (200,000 MTPY) When the proposed expansion is completed in the early 1990s, the plant will be capable of handling 67 percent of Minsk's current waste generation. The mechanical process of the Minsk plant is similar to the operation in Leningrad. One difference is that the Minsk facility uses composting drums that were manufactured by Dano. Evenso, these drums are similar to the Soviet made digesters used in Leningrad. Another difference is that sewage sludge is mixed with household waste in some batches. Concern about heavy metals in the sludges has limited use of this compost mixture to horticultrual use.

Compost from household waste only is used in the same ways as in Leningrad. The outputs of the Minsk plant are also cimilar to those in Leningrad - compost, 67 percent; metals, 4 percent; and rejects, 29 percent. Unlike Leningrad, the rejects in Minsk are incinerated. There are plans to replace the incinerator with a pyrolysis system, as part of the plant expansion. In addition, experiments are being conducted on ways to recover plastics, glass, and non-ferrous metals to reduce the level of rejects.

Recovery of compost from a landfill is being experimented with in Leningrad. A portion of the old section (10 years) of the landfill that receives only household waste is being excavated. The material is screened. Decomposed waste (compost) is used on agricultural land and the rejects are returned to the landfill. This experiment was initiated to reduce the rate at which space was being consumed at the landfill.

Energy Recovery

There are two energy recovery plants in Moscow. An additional 10 plants have been built in the country, see Exhibit 2.

EXHIBIT 2

ENERGY RECOVERY FACILITIES IN THE USSR

City	Republic	Technology	Facility Size (tons per day)	Year of Commission
Dnepropetrovsk	Ukraine	DBA	1,584	1987
Kharkov	Ukraine	DBA	1,188	1982
Kiev	Ukraine	DBA	1,584	1988
Moscow	Russia	Martin	440	1974
Moscow	Russia	Volund	1,200	1983
Murmansk	Russia	DBA	792	1984
Pyatigorsk	Russia	DBA	1,188	1982
Rostov	Russia	DBA	1,188	1983
Saratov	Russia	DBA	1,188	1986
Soc	Russia	DBA	792	1982
Vladimir*	Russia		200	1982
Yalta	Ukraine	DBA	1,188	1981

DBA - Deutsche Babcock Anlagen

* Soviet developed mass burn plant.

About 10 percent, or 343,000 TPY (312,000 MTPY) of the waste discarded in Moscow is processed by the waste-to-energy plants. Landfills are used to dispose of the balance of Moscow's solid waste. These landfills are 50 to 60 miles (80 to 100 kilometers) from the city.

The Moscow energy recovery plants use Martin and Volund systems. The handling and combustion process is the standard approach used in energy recovery/incneration plants. Electrostatic precipitation (ESPs) are used for air pollution. Energy is recovered from the incineration process in the form of steam, which is used in the city's district heating system.

As shown in Exhibit 2, energy recovery plants are being built in the Soviet Union and there are plans for additional facilities. Public concern about air emissions have restricted development of energy recovery as a disposal alternative.

Landfill

Each of the cities visited had at least two landfills and as many as four. At one of the Leningrad landfills, for example, waste is received twelve hours per day. The landfill is illuminated during the winter because of the limited sunlight. Cold and snow can also present operational problems, but these were reported to be limited obstacles in part because waste is collected from the apartment buildings daily. This minimizes the extent to which waste freezes in the containers and, thus, is difficult to unload. Cover material is placed in areas of fill that not actively receiving waste. The working face of the landfill is not always covered on a daily basis. This landfill began operations in 1978 and was 56 feet (17 meters) above the surrounding area. The forecast future height of the landfill is over 80 feet (25 meters).

The use of liners at landfills is being investigated nationwide by the U.S.S.R. Academy of Municipal Economy. Synthetic liners were reported to be in limited use. At the example Leningrad Landfill, the bottom of the site is clay. A drainage ditch has been dug around the fill area. Water in the ditch is directed to a retention pond. The collected water is re-circulated into the Landfill. Monitoring wells were installed around the landfill to monitor for contamination of the groundwater by leachate.

Recovery of landfill gas on a demonstration basis is being done at two landfills in Moscow. There has been limited interest in methane recovery because of abundant material gas supplies in the Soviet Union.

Solid Waste Protocol

One result of the trip was the signing of a Protocol agreement between the Soviets and members of the delegation. The intention of the Protocol is to foster the sharing of information in solid waste management. Another objective will be to develop commercial joint-ventures should opportunities arise.

Signing for the Soviets were Yuri Volchek, Deputy Minister, Ministry of Municipal Economy, BSSR, Viktor Zhdan, Head Engineer, Department of Scientific and Technical Development, BSSR and Vjacheclav Volkov, representing the Ministry of Housing and Municipal Economy, Moscow.

Specifically, the Protocol establishes:

- Recognition of mutual concerns about, and determination to effectively deal with, the growing problems of solid waste management and, in particular, the collection, transportation, treatment/recovery and disposal of non-industrial solid wastes;

- New initiatives to be taken to launch and regularize exchange visits by experts in various related fields of solid waste management;

- An agreement to pursue scientific and technical cooperation, including design and engineering activities;

- An agreement to foster and pursue U.S.-U.S.S.R. joint venture possibilities between designers, manufacturers and others involved in various aspects of solid waste management; and

- A six month target to formalize a visit to North America Soviet delegation of solid waste management specialists.

POSSIBLE FUTURE TRENDS FOR MANAGEMENT OF HAZARDOUS WASTES IN OECD MEMBER COUNTRIES

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1. The Organisation for Economic Cooperation and Development (OECD) is concerned with helping to achieve high economic growth, employment and a rising standard of living in its twenty four Member countries. These countries are Austria, Belgium, Denmark, the Federal Republic of Germany, Finland, France, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey and the United Kingdom in Europe, Australia, Japan and New Zealand in the Pacific and Canada and the United States in North America. Yugoslavia participates as an adjunct Member. Note that all twelve underlined countries comprising the European Economic Community (EEC) are Member countries of the OECD. Policies and practices concerning waste management differ in each OECD Member country as compared to the others.

2. Countries have approached the issues of waste management from very different points of view in Europe. For example, very tight controls are in place concerning all wastes in the FRG. On the other hand, the Italian Environment Minister said in May, 1987 that only one properly functioning "official" site exists for disposal of hazardous wastes but that "other hazardous wastes are disposed by private enterprise, very often with little or no regard for legal requirements".

3. Denmark, Sweden and Finland, countries with small populations which are relatively concentrated into certain areas have opted, in the case of hazardous wastes, for centralized multi-functional (incineration, physico-chemical treatment and controlled landfill) facilities largely capitalized with public funds. Flow control is applied to ensure that these facilities receive the wastes.

4. The U.K. and France both take the view that very careful land use planning can help to ensure that current waste disposal activities will not create future threats to man and/or the environment. Both countries assert that nineteenth century Acts requiring stringent land use review and public permission have largely prevented the uncontrolled site problem.

5. All countries are now experiencing difficulties ranging from moderate to extremely severe in trying to site new waste management facilities. New hazardous waste sites are almost impossible to obtain in Western Europe and Japan. Australia is also having great difficulty in this respect. In Europe, the practice is now to enlarge existing sites rather than to seek new ones. Export (often to eastern Europe) and disposal into the sea currently ease capacity problems. There are rumors that certain offers have been made to finance hazardous waste disposal facilities in other countries who would then guarantee to accept wastes generated in the financier's country.

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* The views expressed are solely those of the author and not necessarily those of the OECD or its Member countries.

Ireland and Luxembourg apparently export their entire generation of hazardous wastes for disposal elsewhere. New sites are often proposed in border areas; a storage site for hazardous wastes comprising about 350 acres is scheduled to be placed very near the Dutch border in the FRG village of Wemb.

6. The European Community possesses about 10 000 uncontrolled waste sites which are likely to require clean-up according to two 1987 reports [1],[2]. In spring 1988, the annual cost for these clean-ups was suggested to be about $6 per capita or about $2 billion each year for the next fifteen years by the Director-General for Environment of the Commission of the European Communities. But these estimates may be too low. For example, in 1988 Danish authorities indicated that their 1985 inventory of uncontrolled sites had failed to identify fully half the sites requiring consideration.

7. Some countries do not fully control on-site disposal of hazardous wastes at present. This situation is gradually changing. Controls including full scale licensing requirements and inspections/audits are unlikely for all on-site disposal operations in all countries, however. For EEC countries, all hazardous waste disposal operations, on-site or off-site, eventually will require a full-scale environmental impact assessment (EIA) in order to operate legally. Exactly how countries will apply the EIA requirements in order to better control on-site disposal facilities is not clear at present.

8. In certain areas, governmental entities have helped to defray capital costs of disposal facilities by means of grants from general funds. Facilities in Belgium, Denmark, Finland, Sweden, FRG and Holland have been included in such approaches. These infusions of capital have sometimes been accompanied by funds from the generators who will be served by the facilities; for example, SAKAB in Sweden is 4% generator owned, while GSB in the FRG is 30% owned by 53 generators. On the other hand, all 21 transfer stations plus the central facility in Denmark were capitalized by public funds. Facilities which have received significant infusions of public funding for capital construction are usually integrated central disposal facilities containing a high temperature incineration operation backed by physico-chemical treatment and controlled disposal into/onto land.

9. At present, all of OECD Europe generates about 20 to 24 million tonnes of hazardous wastes per year or about 55 kg per person. Generation is probably increasing by about one to two percent per year. Of this total roughly 1.5 million tonnes are incinerated (5 to 8 percent), 700 000 tonnes are inserted into the high seas (2 to 5 percent), between 1.5 to 3 million tonnes are subjected to some recycling/reclamation operations (5 to 12 percent), about 1 million tonnes are sent to physico-chemical treatment facilities (4 percent) and the remainder comprising 14 to 18 million tonnes is disposed into/onto land (70 to 75 percent).

10. Considerable quantities of hazardous wastes are exported from various countries. In Europe there are over 100 000 annual transfrontier movements of hazardous wastes (roughly one every five minutes, 24 hours per day, 365 days per year). Many of these shipments are destined for Eastern European countries and some are proposed to go to developing countries. Strong international efforts are under way to control this traffic. For example, the OECD is developing an international agreement in this context, and the United Nations Environment Program is attempting to achieve a worldwide Convention.

POSSIBLE FUTURE TRENDS

11. The major areas for new action will probably include:
    - 11.1 Reduction of hazardous waste generation;
    - 11.2 Stepped up recycling/reclamation programs;
    - 11.3 Prescription of disposal routes for various types of hazardous wastes:
    - 11.4 Upgrading of landfill standards;
    - 11.5 Better monitoring and control of "on-site" disposal operations;
    - 11.6 Definition of programs for dealing with uncontrolled waste disposal sites;
    - 11.7 Preventing current disposal operations from becoming future problems;
    - 11.8 International cooperation to control inappropriate exports; and
    - 11.9 International harmonization of legal and technical standards for definition and management of hazardous wastes

Reduction of hazardous waste generation

12. All OECD Member countries encourage waste reduction in general terms. In many instances this encouragement takes the form of promoting the use of so-called low and non-waste technologies. Research funds and occasionally subsidies are available for pursuing such technologies. Often, governments work cooperatively with firms in order to improve individual unit operations. In some cases, countries see the possibility of clean technology as a means of increasing international competitiveness (France, Holland) or as a profitable export item (Holland, Japan, Finland). The EEC has a program to provide grants for development of low and non-waste technologies. Norway regulates the industrial sector in order to minimize potentially hazardous wastes.

13. Some countries have taken legislative/regulatory steps to reduce hazardous wastes by reducing or eliminating certain constituents from products. For example, Japan and Holland both intend to reduce mercury and cadmium in batteries and have made substantial progress in this direction. Denmark and Sweden do not allow cadmium and certain phenols into most products but require substitute materials. Other countries will probably adopt such approaches in future.

14. Perhaps the strongest legislative approach to date is that of the Federal Republic of Germany (FRG). The Waste Avoidance and Waste Management Act of 27 August 1986 places absolute primacy on waste reduction and recycling/reclamation of wastes "necessarily created". The FRG Parliment is to decide which waste streams must be reduced and place these into priority order. Then the percentage reduction will be decided and all generators will be forced to achieve this reduction. There will be, however, the possibility for subsidies to affected industries for achieving reduction and substitution in products for components which might be harmful if improperly disposed.

15. In implementing this Act, the approach of the FRG government is to develop codes of practice in cooperation with generators, recyclers, etc. rather than regulations. The Federal Minister of the Environment is discussing the policy objectives with these parties of interest in order to determine the extent to which cooperative measures can be implemented. If this process stalls or even fails, then waste reduction will be enforced by means of regulatory actions [3].

Stepped up recycling/reclamation programs

16. Many countries are increasing research efforts to provide means to recycle/reclaim useful materials from specific waste streams. For example, green salt recycling from titanium dioxide is being investigated as is regeneration of foundry sands. The non-ferrous metallurgical industry is increasing its efforts to win metals from wastes otherwise destined for disposal. Dozens of other examples could be cited.

17. From a policy point of view, once an economically useful recycling method is proven for wastes which were otherwise being disposed, recycling is encouraged by curtailing of disposal capacity for these wastes. For example, in the FRG, greensalt is not allowed to be inserted into the sea since it can be recycled economically.

Prescription of disposal routes

18. There is a growing trend for government to prescribe which waste streams may be disposed by a given disposal option. Austria and the FRG both provide indications for each waste in their respective lists. Certain wastes may not be disposed into/onto land under any circumstances; for example, all liquid organic hazardous wastes must be destroyed. Almost no hazardous wastes can be legally disposed into/onto land in Holland and Denmark. Incineration, especially of the rotary kiln type, is on the increase. Significant new capacity is planned or under construction in Holland, Belgium, Switzerland and the UK. The FRG has indicated the need for at least ten new incinerator sites in future [3]. Adaptation of cement kilns for incinerating pumpable hazardous wastes is likely to increase as well.

19. There is a fairly general trend to reduce and eventually eliminate legal disposal of hazardous wastes into a marine body. The FRG will phase out virtually all ocean dumping by 1990. Many other countries already have virtually ceased to allow this disposal route. Belgium has recently required an advance payment of 50% of anticipated costs for each applicant who requests an annual Permit to dump wastes using Antwerp as the port of debarcation. This prepayment for dumping "capacity" has sharply cut the number of requests for Permits. The Commission of the European Communities has proposed to EEC Member states that sea dumping of hazardous wastes be essentially eliminated by the late 1990's. In June 1987, the Belgian environment minister announced that on 1 January, 1990, titanum dioxide waste dumping in the North Sea from Belgian ports would be banned; this will affect about 600,000 tonnes of wastes annually from all over Europe (about 3% of total annual hazardous waste generation).

20. -A move to ban the incineration of hazardous wastes in European waters was blocked by Ireland, Spain and the U.K. in June, 1987. The FRG could accept 1994. Denmark, Finland, Norway and Sweden could accept a ban by 1991. Note that the Oslo Convention signatories have agreed that a final termination date for incineration of hazardous wastes at sea will be selected before the end of 1990. Belgium will prohibit the use of Antwerp as a port for ocean incineration on 1 January 1995. According to Belgian officials, this move will virtually halt ocean incineration in Western Europe since over 90,000 of the 105,000 tonnes submitted to this operation annually would be affected. These changes will inevitably increase pressures for more disposal capacity on-shore.

Upgrading of landfill standards

21. In the FRG, the states set landfill standards; these have been variable in the past, but are now approaching more uniformity in response to national legislation. Landfills operating prior to enactment of national legislation are allowed to continue to operate on their former basis. A "typical" landfill today is designed to rest on clay liners ranging from 50 to 100 cm thick, permeability of 10^{-8} cm/sec; sidewalls are the same. Leachate is collected in its entirety and sent to a physico-chemical processing plant for treatment. Roughly one tonne of leachate is collected for each seven tonnes of waste deposited. Costs range from $40 to $150 per tonne deposited. A special depository in a deep salt mine is used to store 90,000 tonnes yearly of drummed highly hazardous wastes.

22. Recently, the FRG decided to move toward double synthetic liner systems for landfills licensed to accept wastes classed as hazardous. Trends toward "absolute" isolation of wastes disposed into/onto land are on the increase. Holland and Japan both are using concrete bunkers for placement of wastes. Sweden and Finland have developed special asphalt based cells to receive solid and some sludgy hazardous wastes.

Better monitoring and control of "on-site" disposal operations

23. Steps are being taken to force "on-site" disposers to meet all local, regional and national standards applicable to hazardous wastes. This process will continue in Western Europe until all on-site disposal operations are fully covered. In turn, this process is creating pressures for more communal disposal sites especially incineration and physico-chemical treatment centers.

24. The trend in central and northern Europe is to establish such treatment centers as quickly as possible. As noted, the FRG government has declared that ten more are needed as a minimum. Switzerland will site at least one or two in the near future. Scandinavia is expanding its existing centers. Regional centers for wastes from several countries are being discussed as possibilities for the future.

Definition of programs for dealing with uncontrolled waste disposal sites

25. Many European countries address the uncontrolled site problem in a "react and cure" mode, i.e., respond as the need arises. There are, in fact, relatively few national laws directly relating to uncontrolled sites. This situation was recently examined by the European Parliment which urged a new EEC program to "identify and reclaim abandoned landfill sites". However, the European Commission Environment Commissioner responded that the "Superfund experiment" in the U.S.A. held no particular attraction for the Commission. Still, the Commission is attempting to inventory old waste sites, and some EEC funds are available for the identification and restoration of former landfills under a special Regulation which came into force in 1987. Note that there is a 1980 EEC Directive on protecting groundwater from pollution. Theoretically in EEC countries, all waste disposal operations must comply with this Directive. Yet, some countries have been condemned by the European Court for not having applied this Directive.

26. The EEC intends to develop policy proposals for dealing with contaminated soil. This task will be complicated since each country has a different approach. For example, funds for clean-up in Holland and Denmark are taken from general revenues. In Denmark, there is no strong concern about potentially responsible parties. Rather the object is to clean-up

"mistakes of the past and not to allow these mistakes in future." Industry sometimes voluntarily participates in clean-up operations in Denmark. Holland also uses general funds for clean-up activities but has, to date, brought about 35 lawsuits to recover costs from potentially responsible parties. Combined, the government is seeking to recover about $150 million from the 35 defendants. In the FRG, the state governments are responsible for obtaining clean-up funds. This situation is considered unsatisfactory by certain parties-of-interest. The federal government is reviewing the situation with a view toward possible policy proposals in future. The Commission of the European Communities proposed a strict (but not joint and several) liability scheme for uncontrolled sites, but this proposal was rejected upon its first presentation. In future, however, this approach is likely to eventually be adopted.

27. There are extensive research programs and new techniques being developed for remediation of contaminated soil. There are a variety of thermal techniques meant to drive off and destroy volatile organic compounds. There are many innovative "isolate and control methods" [4].

Preventing current disposal operations from becoming future problems

28. The monitoring and postclosure issue is becoming of increasing importance with respect to hazardous waste disposal into/onto land. For example, in the UK, a license holder can simply turn his license back to the Authority and depart. In Japan, where almost all so-called "harmful wastes" are landfilled into specially designed cells, (isolation by concrete 15 cm thick having unconfined compression strength of 250 kg/cm^2; covered to prevent rainwater intake; leachate collection pits) the Permit holder must merely prove that environmental standards are fully met on the date he surrenders the Permit. He is then free to do as he pleases with the site. The Japanese government is concerned that such sites may become future problems. Since Japan has a law (Public Law 111) to compensate parties injured by pollution incidents, such problems could be very costly.

29. France is developing a scheme to provide insurance against any damage or threat of damage to groundwater from landfills. Yet, the key issue is likely to be early warning and prevention by means of appropriate monitoring schemes. Codes of practice for monitoring and post-closure activities are being developed by OECD and by certain countries such as the UK, FRG and Switzerland.

International cooperation to control inappropriate exports

30. -Governments have decided that hazardous wastes must be subjected to close scrutiny. Such movements will need to be prenotified to the competent public authorities prior to shipment. In most cases, these authorities must formally acknowledge the prenotification; the authorities may also object, in which case, shipment cannot occur until the objection is settled. This regime applies to all EEC countries and is soon expected to apply to OECD countries. Less complex controls will be applied to hazardous waste streams being sent internationally for recycling/reclamation operations. Stringent controls concerning hazardous waste exports from the OECD area already have been approved.

31. Automation of tracking systems is being investigated on a cooperative basis by some countries, the CEC and OECD. A pilot experiment is being devised to test the results. Automated tracking may be available by 1989.

32. As noted, the United Nations Environment Program is attempting to develop a worldwide Convention to control transfrontier movements of hazardous wastes. This work is scheduled for completion sometime in 1989.

33. By 1990, a valid control scheme should be implemented to control international traffic in hazardous wastes. This scheme will need "field testing" before its full consequences can be estimated.

34. A number of countries including Denmark, Sweden, Finland and Holland forbid or tightly control exports of hazardous wastes. The purpose is to ensure that local capacity is fully utilized and to minimize the possibility of improper disposal elsewhere. As outcries against certain waste exports increase, tighter flow control can be expected. Again, pressure from this lost "capacity" can be expected to act as an impetus for waste reduction and recycling/reclamation.

Harmonization of legal and technical standards

35. All OECD Member countries except Iceland and Turkey have issued definitions accompanied by a list of potentially hazardous wastes. Greece has not issued specific guidance but adheres by reference to the definition and list given in Directive 78/319/EEC. All definitions and lists which have been published differ from one another in various details. For example, some country tabulations are set out in generic terms, (paint wastes, solvent wastes, oily wastes, etc.) while others are more specific with respect to constituents (wastes containing mercury, wastes containing PCB's, etc.). Some countries such as Holland, Japan and Luxembourg include concentrations as a basis for deciding if a waste stream is to be controlled as potentially hazardous. The generating activity (steel manufacture, synthetic organic chemicals production, etc.) is pinpointed by some countries, e.g., France and Italy. Some countries combine a number of these classifiers in order to monitor and control hazardous wastes. The OECD and the Commission of the European Communities (CEC) have cooperated to develop a computerized cross-referencing system for all of the published list of hazardous wastes.

36. A major step toward uniformity was taken on 27 May, 1988 when OECD Member countries (except Australia and Spain) agreed to definitions of "wastes" and "disposal" and to a core list of wastes to be controlled in international traffic. The CEC will propose a similar approach and list for its twelve Member states. In June 1988, at a UNEP meeting, this approach was adopted in principle for world wide use.

37. These actions should help in improving understanding of what is a waste and what makes a waste potentially hazardous. OECD Member countries have declared their intent to try to harmonize technical standards for managing these wastes. To this end, work is in progress concerning codes of practice for solvent waste management and landfill. Development of these and other codes of practice is likely to be the foundation for much future activity in management of potentially hazardous wastes.

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MANITOBA SOFT DRINK RECYCLING: A VOLUNTARY SUCCESS STORY

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Introduction

Manitoba Soft Drink Recycling Inc. is unique, as the only Voluntary/Non-Deposit Buy-Back system for Recycling used beverage containers in Canada. Over the past two years we have provided Manitobans with a system of collection which has proven as effective as other models in removing these containers from the waste stream. This has occurred without burdening the consumer or government with the punitive and unnecessary costs that are associated with other collection models.

M.S.D.R. was set up by the soft drink industry and its suppliers to collect two types of soft drink containers: the Aluminum Beverage Can and the Plastic Soft Drink or P.E.T. Bottle. Both containers are recyclable; the aluminum can into new aluminum containers and the P.E.T. container into other consumer uses such as fibre fill, etc. The industry recognizes that the challenge presented by these two container types is in fact "two-fold." While solid waste is a definite concern, litter is a problem which also must be addressed in any program designed to recycle these containers.

We believe that responsibilities for recycling must be met not only by the industry but also by those individuals who consume these products. However, these responsibilities must be met in a positive, cost effective and fair manner. The level of attention directed (both political and financial) must be indicative of the role which these containers play in the overall problem of solid waste.

Operation and Structure

M.S.D.R. operates a "two-tiered" system of collection throughout the Province of Manitoba. The first tier or primary form of collection involves the use of redemption centres and mobile recycling units which travel the city of Winnipeg and the rest of the province on a regular schedule. The mobile units or "Recyclomobiles" operate on a two week or three week rotating basis. The "Recyclomobiles" are located on site at grocery stores, shopping malls and other appropriate point-of-purchase locations. At present, M.S.D.R. operates 20 locations in the City of Winnipeg and 13 locations in rural communities around the province.

The second tier involves donation depots set up by non-profit organizations in communities not regularly serviced by a recyclomobile or permanent facility. Containers are accepted by these groups on a voluntary donation basis and are in turn redeemed through M.S.D.R..

Consumers are paid for their containers using a volume-based pricing system. Payment is made on a per-pound basis, as opposed to per-container. No distinction is made by M.S.D.R. for brands, sizes, etc., as all prices paid reflect the intrinsic value of the materials. This contrasts with models which require all cans and bottles to be dealt with individually: counting, separation and charge-back to the brand.

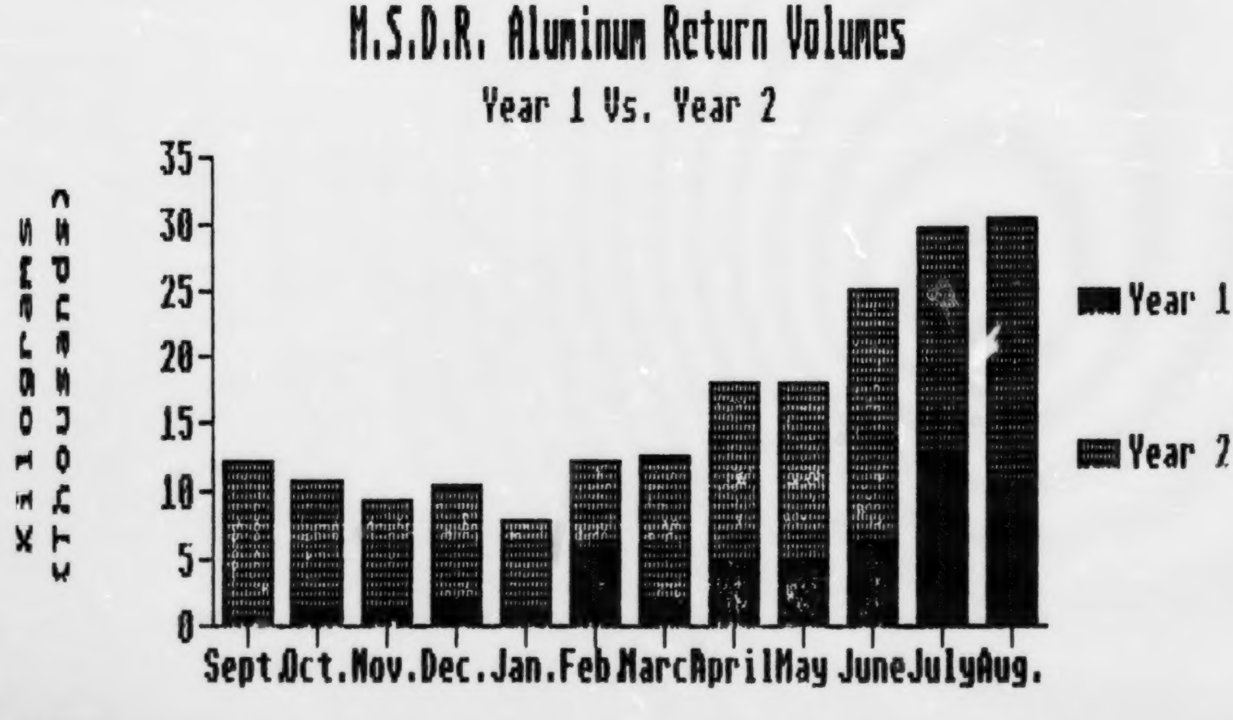
In addition to buy-back being offered to consumers by M.S.D.R., Manitobans can also sell their aluminum beverage containers to a number of scrap metal dealers in operation throughout the Province.

Two Year Summary

Since beginning operations in September of 1986, M.S.D.R. has recycled 195,618 kgs. of aluminum beverage containers and 54,560 kgs. of P.E.T. containers. During this same time period, provincial scrap dealers accounted for an additional 190,449 kgs. of aluminum soft drink containers. Actual growth rates for return volumes have been steadily increasing from year to year. The following graph and chart provide a direct comparison for aluminum recovery from year one to year two by M.S.D.R..

M.S.D.R. ALUMINUM Return Rates Year 1 Vs. Year 2 (Kilograms)

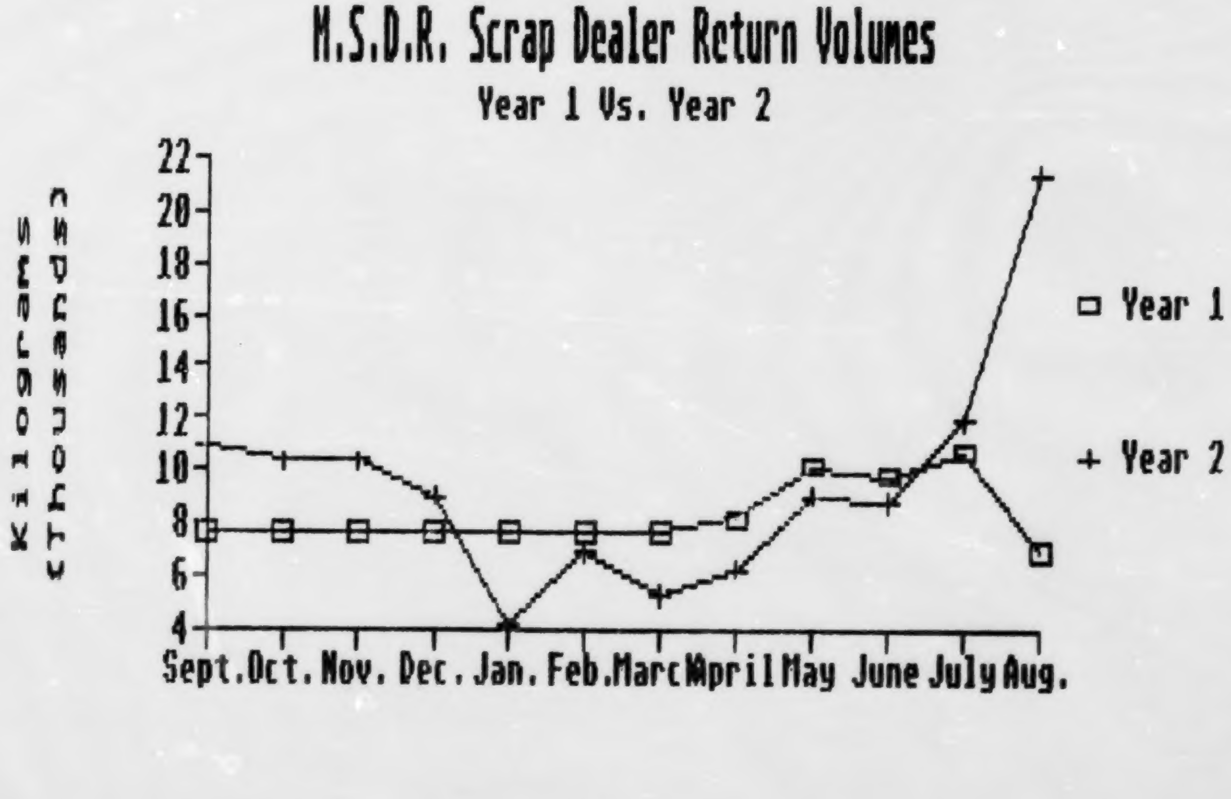
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Total
Year 1	180	1333	817	2029	1122	5285	1824	4405	4834	5933	12519	10454	50736
Year 2	11880	9476	8246	8234	6566	6888	10554	13489	12889	19046	16946	19669	143882
%Change	98%	86%	90%	75%	83%	23%	83%	67%	62%	69%	26%	47%	65%



At the same time the growth experienced by M.S.D.R. has not been achieved at the expense of the scrap dealers in the province. Overall we have seen an increase in the amount of material being recovered. The following charts demonstrate this point.

Scrap Dealers ALUMINUM Return Rates Year 1 Vs. Year 2 (Kilograms)

	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Total
Year 1	7650	7650	7650	7650	7650	7650	7650	8136	10081	9733	10687	6930	99117
Year 2	11025	10350	10350	9000	4102	6900	5284	6277	9017	8768	11873	21335	114202
%Change	31%	26%	26%	15%	-46%	-11%	-30%	-30%	-12%	-11%	10%	68%	13%

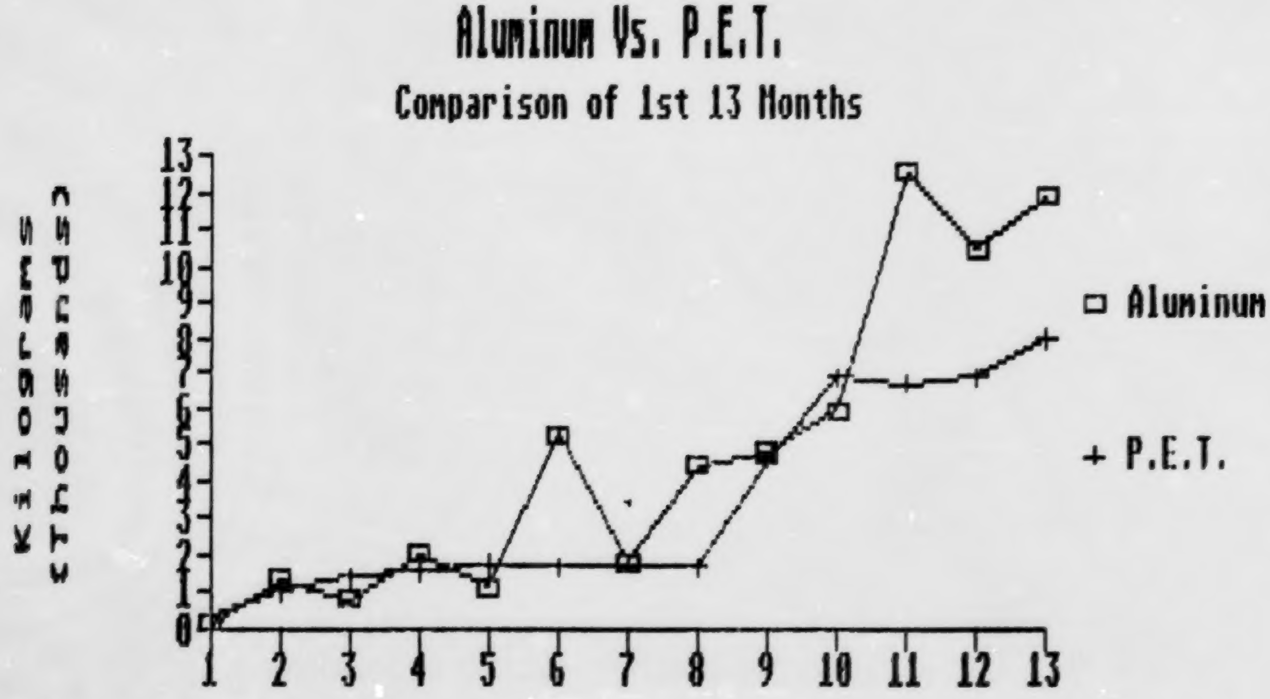


Redemption rates overall in year one were approximately 22% for aluminum soft drink containers. During year two, an average return rate of between 40 and 45% is anticipated. The important point is that after two years, M.S.D.R. is reaching return levels which are comparable to those being achieved using deposit systems.(Alberta for example has been estimated to have an average return rate at between 40 and 50%, achieved after ten years). We believe that after year three we will surpass Alberta return rates on aluminum cans.

P.E.T. has experienced strong growth as well since we included it in our program beginning in July of 1987. Indications are that P.E.T. return rates and volumes are approximately one year behind aluminum. The following charts show P.E.T. growth since 1987 and provide a comparison to M.S.D.R. aluminum returns during its initial 13 month period.

Aluminum Vs. P.E.T. Comparing 1st. 13 months

	1	2	3	4	5	6	7	8	9	10	11	12	13
Al.Yr.1	180	1333	817	2029	1122	5285	1824	4405	4834	5933	12519	10454	11889
PET.Yr.1	371	1039	1402	1598	1718	1694	1700	1665	4559	6840	6667	6843	7950



Education, Programs, Promotions and Advertising

The principle mandate of MSDR has been the removal from the waste stream of used soft drink beverage containers. An integral part of this mandate has been the public awareness and educational programs which have been undertaken by MSDR to fulfill this goal. These programs have involved different approaches to the problems of recycling and have attempted to address directly both litter and land fill reduction as the goals of our program.

In addition to our regularly scheduled services, MSDR provides community groups, nonprofit organizations and individuals such as seniors with direct collection services. We pick up directly for such groups as the schools, mentally handicapped groups, churches and others. We currently have over 500 non-profit groups which participate in the,program.

We also assist these groups with the promotion and collection of these materials. We provide free of charge to groups such as schools and community centres, specially designed collection bins and promotional materials. These bins have provided participating groups with an easy and effective collection tool. At the same time MSDR has developed a public presentation package which is used in speaking to schools, community groups and any one requesting help in setting up a voluntary recycling program.

We have also developed a record keeping or account system for nonprofit groups. Under this program members or even non-members of organizations can deposit materials with MSDR and have the funds credited to an account of their choice. At the end of each month the reciepts are tallied and the appropriate organization is sent a cheque for the amount collected. In addition we also have special price bonuses available to non-profit organizations.

We have also targeted children as an important component of the recycling population. We are working with the Fort Whyte Centre for the Environment (a local environmental studies centre in Winnipeg) and have developed a recycling awareness program called the "Class Recycling Challenge". This program entailed the construction of a large collection bin at the centre to collect materials from those classes attending the centre on field trips. Under the program the class which collects the most materials will be awarded with family passes to the centre and a year-end picnic for friends and family sponsored by MSDR. All funds raised will be used by Fort Whyte for developing further student education programs at the centre.

We also operate programs at a number of High Schools within the city and rural areas. We have also developed specific programs for the Universities of Winnipeg and Manitoba. This involves the placement of bins on each campus as well as sponsoring and participating in information sessions and social activities designed to promote voluntary recycling.

Our program has also led to the creation of new programs of training and employment at various centres for the mentally and physically handicapped in the province. Material collection, sorting and crushing is providing a source of revenue and experience for such groups as Arc Industries in Selkirk and Altona and other centres throughout the Province.

We get involved in the community and we realize that for recycling to succeed, we must maintain a positive public profile and role. We participate with such groups as the Recycling Council of Manitoba in their programs as well as serving on the board of directors for the National Environment Week Festival held annually each summer.

To assist those communities not currently serviced by an existing MSDR route, we are working to identify those community groups, who with our assistance, would be interested in setting up collection systems in their community. We provide collection bins and promotional materials along with setting up a method for transporting the materials to Winnipeg for redemption.

Costs/Benefits:Voluntary Vs. Deposit

In addition to removing the containers from the waste stream there have been other direct and indirect benefits generated by MSDR and the scrap industries.

The first direct benefit has been the net return of dollars to the community without any direct costs either to the community as a whole, the soft drink consumers or the tax payers through government costs created by intervention.

MSDR and the Scrap Dealers of Manitoba have, during the course of this program, placed approximately $500,000 back into the community through redemption payments. These dollars have gone not only to individuals but to a number of nonprofit and community based organizations. These dollars represent newly generated funds, not simply a re-distribution of consumer incurred costs.

In addition to a direct dollar return achieved by the community, various indirect cost savings have also been generated by this program:

-Municipal governments experience an immediate cost savings in reduced costs for garbage pick-up and waste disposal. In the city of Winnipeg, the costs for residential waste removal are estimated at $60 per metric tonne. As these costs are increased by governments to reflect the true costs of waste disposal, the savings realized by this program will continually increase in direct proportion. At the same time costs are reduced for institutions such as schools and universities as well as private enterprise where litter pick-up and waste disposal volumes are reduced.

-Demands on government are reduced or at the very least, new demands are limited as recycling provides a source of fund raising for nonprofit and community groups. At the same time, no indirect costs are associated with this form of fund raising in that under a deposit system, if nonprofit groups redeem material they are in fact collecting the taxes or value placed on the product which have been paid by society already in the form of handling charges and deposits. There is no new generation of wealth.

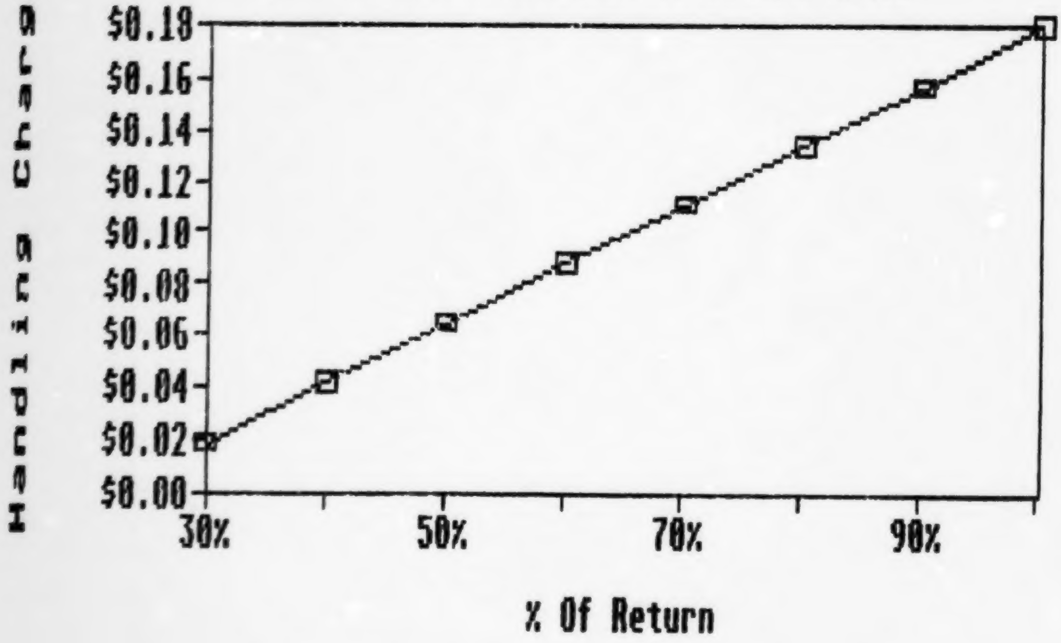
As MSDR has worked towards the development of a strong voluntary recycling program, it has also protected the consumers of Manitoba from being forced to pay additional and unnecessary charges. In other jurisdictions these charges have cost consumers and taxpayers millions of dollars.

Costs under a deposit system would not remain constant. Container fees would actually be forced to rise as more materials are redeemed. Under deposits, the handling charges passed on to the consumers reflect the costs of handling only the returned containers. As returns increase, handling charges must also be increased to reflect higher costs and to replace the diminished levels of un-redeemed deposits available to cover costs. The setting of these costs is removed from the market place and placed in the regulatory system. Recyclers of the materials have no incentive to operate on an efficient basis. When their profit margins start to drop they appeal for higher fees.

The following model demonstrates this point. I have set up the model based on a population which consumes 24,000,000 cans of soft drinks per year. It is estimated that during the first year a deposit of $0.05 per container and $0.02 per container handling charge will be used. These amounts are established as the dollar levels required to pay for the system to operate at a level of 30% return during year one. At a 30% return level, $840,000 in un-redeemed deposits and $480,000 in handling charges will pay for the system. The net cost to the system for each container returned is approximately $0.18. This is based on available dollars divided by the containers returned. If we assume that costs under this system rise proportionally to amounts handled, higher returns will create a short fall of available dollars to meet costs. Thus the handling charges will have to be raised to make up the difference. The following chart illustrates this point.(Based on the above scenario)

Handling Charge For Beverage Containers

A Direct Relation To Return Rates



Soft Drink Containers are estimated to make up only between 2% and 3% of the solid waste stream. The examples used above would indicate that it would be a terrible waste of dollars and public energy to single out these containers for attack, when the overall solid waste issue must be addressed. It is our belief that by singling out these containers for action, you are in fact limiting the opportunities for future developments in the area of waste management.

We believe that the lessons learned in our program are applicable to other articles in the waste stream. People realize that materials have an intrinsic value, and they have come to expect that not all materials' represent the same dollar value. People can be taught to recycle for the right reasons, and be made to see the long term benefits.

At the same time we must recognize that Aluminum beverage containers and P.E.T. bottles have the most value of materials found in the waste stream. Even though they make up the smallest percentage, their artificial removal from the entire system would inhibit the growth of other programs as these dollars would not be available to help cover recovery costs.

The Future

M.S.D.R. intends to continue and expand operations to include more communities within the Province. Like the Soft Drink Industry itself, our organization is consumer responsive. As other waste management projects come into play in Manitoba, we will be more than willing to share our expertise and to ensure a market for any of the containers collected that fall within our mandate.

RECYCLING 'MAKES CENTS' IN MANITOBA

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"Your Lead-Acid Batteries -
A Negative Charge to the Environment"

Brian McIver
Vice-President, Marketing
Nova Pb Inc
Ville Ste-Catherine, Québec

And

Ray Capowski
Industrial Programs Branch
Environment Canada, Ottawa

INTRODUCTION:

Good afternoon Mr. Chairman, Ladies and Gentlemen. Firstly, I would like to thank you for the invitation to address the Canadian Waste Management Conference.

Secondly, I would like to point out that this presentation is effectively a joint effort in conjunction with the Industrial Programs Branch of Environment Canada. As you will see, I have taken the liberty of sourcing a lot of the information and data contained in this presentation from a report commissioned by Environment Canada, which was completed in July of this year.

When one thinks of waste minimization, it more often than not, involves not only new procedures for handling the waste stream but also new equipment and new technology. Often the equipment is very capital intensive in nature and the new technology is unproven in terms of its technical, commercial or environmental viability.

In the case of minimizing the waste from spent lead-acid batteries however, the circumstances are exactly the opposite. In other words, the necessary equipment and technology currently exists in Canada to recycle all the spent batteries generated within Canada. Also, the technology has been in place for several decades. Ten years ago, a scrap dealer could give you five or six dollars for an old car battery. Like the stock market however, the price of this commodity can also rise and fall. Today, a scrap battery is worth a dollar fifty or less. This metal, more so than most other metals, is simply being left to rot in the ground. Before someone asks the question "why aren't all spent lead-acid batteries then being recycled?", the answer is essentially the lack of social or economic incentive to do so.

Prior to attempting to answer that question in more complete detail, I would like to review some of lead-acid battery industry, automobile industry and lead industry data and trends.

When one thinks of a lead-acid battery, it is only normal to think of the car battery. Especially in Winnipeg during the month of January.

Table 1 illustrates the growth in vehicle registration that has taken place in Canada from 1950 to date. As can be seen, the number of registrations of cars, trucks and buses in Canada has grown from about 2.5 million units in 1950 to almost 15 million units today. Even though the average growth rate in the 80's at 1.8%, is significantly less than the 60's or 70's at 4.7 and 5% respectively, in terms of the actual increase in motor vehicles per year in the 1980's, it is still about 200,000 vehicles per year or about half the actual increase per year that occurred during the 1970's. According to data from the Motor Vehicles Manufacturing Association, 86% of households in the U.S. have one or more vehicles. Some 33% having 2 vehicles and 19% have 3 or more. I haven't seen comparable data for Canada but I doubt if it is significantly different.

Table 1
CANADIAN MOTOR VEHICLE REGISTRATIONS
1950 to date

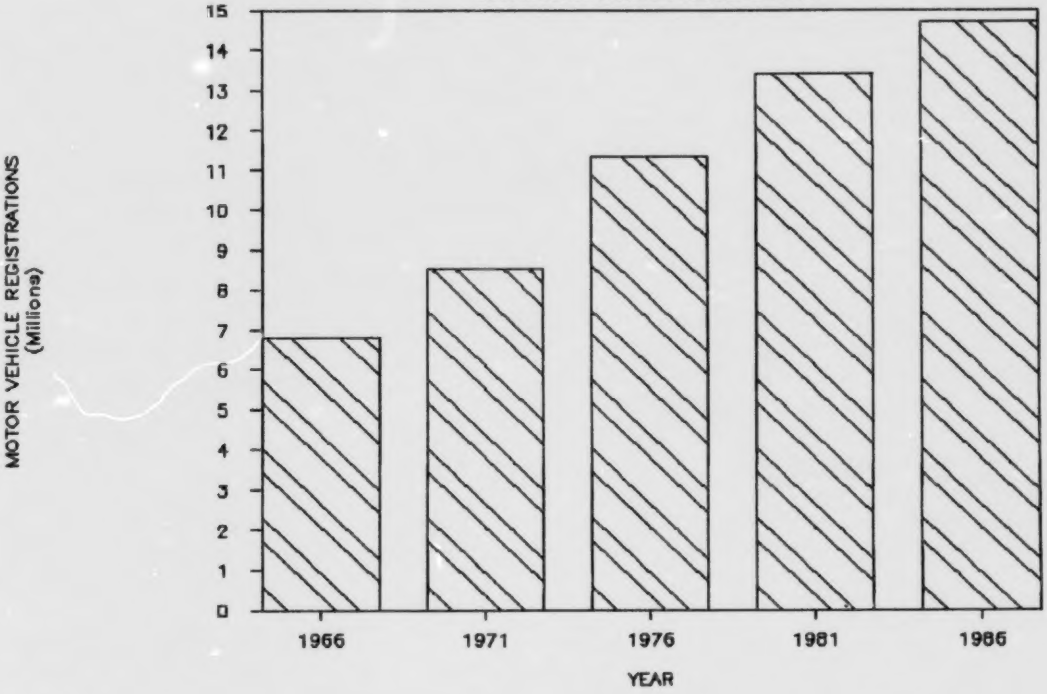
All number in 000's

Year	Passenger Cars	Trucks	Buses	Total	Total % Increase From previous year
1950	1,913	633	10	2,557	
1960	4,104	1,039	18	5,161	4.7 (10 years avg.)
1970	6,602	1,440	41	8,083	5.0 (10 years avg.)
1980	10,256	2,903	53	13,211	
1987 est	11,600	3,200	55	14,855	1.8 (8 years avg.)

Source: Statistics Canada

Table 2 graphically portrays the kind of growth that we have seen. Anyone who has the dubious pleasure of driving their car to work in any major city in Canada probably doesn't have to be told that the volume of traffic is getting worse every year!

TABLE 2



Even though Tables 1 and 2 only highlight the growth in registration of passenger cars, trucks and buses, if one were to include the number of other registered vehicles in Canada such as motorcycles, mobile industrial equipment, farm tractors, locomotives, marine vehicles, snow mobiles, off-road equipment, etc., the total number of motor vehicle registrations would increase by over one million units to approximately 16 million units. In addition, if we were to include the lead-acid batteries used in non-registered applications, such as diesel generating stations, emergency lighting, standby-power applications for hospitals, banks, computer centers and home products such as garden tractors and all-terrain vehicles, the number of lead-acid batteries in use in Canada would again increase by several hundred thousand units.

Since the common car battery represents the lion's share of the application of the lead-acid battery, I would like to highlight some of the events that have occurred in the automotive industry that affect both the volume of lead used in the lead-acid battery and some of the characteristics of the lead-acid battery itself.

Trends in Battery Design:

As everyone is aware, during the 1970's in the wake of the fossil fuel crises in North America, the emphasis in automotive design was on lighter and more fuel efficient cars. Battery design and weight was also affected and the average weight of the battery went from over 50 pounds per unit to under 40 pounds per unit. In fact, the average weight of a new car battery today is about 36 to 38 pounds. The amount of lead per battery has also decreased. The amount of lead per typical car battery once was over 35 pounds, however currently is about 18 to 20 pounds. Also, due to technological advances in battery manufacturing technology, batteries are now lasting longer. During the 1970's for example, a typical automotive battery lasted about 36 to 40 months. Today, the normal life-span of a battery in Canada is about 50 months. I should point out that a typical battery in Canada actually lasts longer than the same battery operating in warmer temperatures such as those in the southern U.S. That same battery under similar operating conditions in the southern U.S. would only last about 36 to 40 months. Just another one of the small benefits of living in Canada. Contrary to popular belief, it is excessively hot weather and the evaporation of the electrolyte which accelerates the death of the battery, not the cold weather. Extremely cold weather however, will quickly remind you that your battery is not in good condition or has to be replaced.

Trends in Automotive Design:

Lets take a look at some of the automotive design trends that have affected the characteristics of the lead-acid battery in use in your car today:

1. Firstly, most cars today have fewer cylinders than a few year ago. It is interesting to note that a four cylinder car actually requires a more powerful battery than an eight cylinder motor due to the increased time that elapses between cylinder ignition. According to the Motor Vehicle Manufacturing Association, only 18.7% of the 1987 model year cars were equipped with V-8 engines. This is down from 28.2% in 1984. Cars with 4 cylinder engines made up 53.4% of the 1987 total factory shipments, with 6-cylinder engines accounting for 27.9%.

2. Secondly, the under-hood temperatures have increased by almost 100^0F in the last 4 to 5 years. Although the objective of this automotive design was to increase the efficiency of fuel combustion and therefore decrease fuel consumption, this increased temperature has a negative impact on the life-span of the battery due to the increased electrolyte evaporation that I mentioned earlier.

3. Thirdly, perhaps one of the most significant trends to affect battery performance and life-span, is all the electronic gadgets in most cars today. This electronic parasitic load used for clocks, the ignition system, fuel system, cooling system, locks, lights, etc., has required a significant increase in battery power and quality. According to manufacturer specification on a Chevrolet Cavalier for example, the cold cranking amperage (CCA) on a new car in the early 1980's required 350 CCA while the same car in 1988 requires 570 CCA's. Other than improved electric power requirements, the recharging specifications of a battery have also changed. At idle, the typical passenger car alternator produces about 45 milliamps, however with all the electric equipment in operation, such as lights, wipers and comforts such as air conditioning and power windows, etc., as much as 75 milliamps are

required resulting in a 30 milliamps draw from the battery. In other words, a battery is required to have a much higher recharging capacity or recycling ability than batteries that simply started cars. What this means, is that in order to achieve these improved performance characteristics, the weight of lead per battery and possibly the average weight of the battery itself may actually see a modest increase during the next few years. This effectively reverses the trend which has been occurring in batteries since 1979 or 1980.

4. Another major trend in Canada and in most of North America, is the slow demise of the railway infrastructure. Although this trend is sometimes reversed during an election year in Canada, the decline in passenger rail service for example, has become a fact of life in most communities in Canada. Public transportation is reported as being the mode of transportation for only 5% of people getting to their jobs. Apparently, over 86% of workers commute to work in a private motor vehicle. I have to assume here, that the other 9% either share a ride, walk to work or have the good fortune to stay home and get paid.

In terms of commercial transportation, trucks apparently accounted for 24.9% of the intercity freight ton/miles in 1987, up significantly from 10 years ago, due to better service and cost-competitive rates than commercial rail.

It is significant to note that in Canada for example, during the 1970's, the average growth in truck population was 7.3% per year as compared to the passenger car growth of 4.5% per year.

Lead Sources:

In Canada during 1987, according to data from the International Lead and Zinc Study Group, Canada produced 226,000 MT of refined lead. 140,000 MT of this came from virgin lead refineries sourced from ore, while the balance, 86,000 MT or 38% of the total, came from lead recycling facilities. Total lead consumption in Canada on the other hand, was reported at 101,000 MT. In terms of total lead production in Canada in 1987 from mines however, it totals 414,000 MT. It is obvious that Canada is a very large lead exporter.

It is interesting to note that in the United States the statistics are significantly different. Of the total refined lead production of 1.028 million metric tons, 654,000 MT or 64% came from the lead recycling industry while the primary lead mines produced 320,000 MT. The U.S., by the way, is a net importer of lead, a lot of it from Canada.

World production of refined lead during 1987, according to the International Lead and Zinc Study Group, totalled 4.234 million MT. Lead mines produced 2.417 million MT and world recycled lead production stood at 2.355 million MT or 56% of the total world lead production of refined lead.

Lead Applications:

Table 3 shows some idea of where lead is used in the U.S. according the U.S. Bureau of Mines. Although comparable data is not available from Canada, the percentages are unlikely to be much different. As is clearly evident, lead consumed in batteries is by far the largest single category and it is growing both in terms of the tonnes of lead consumed by this sector and also as a percentage of total lead consumption. Between 1974 and 1986, the consumption of lead used to manufacture batteries has increased from 53% to 76% of total lead consumption in the U.S.

TABLE 3

U.S. LEAD CONSUMPTION BY MAJOR END-USE
All data is in 000,s of metric tons

PRODUCTS/YEAR	1974	% of total	1976	% of total	1981	% of total	1986	% of total
Batteries	773	0.53	746	0.55	770	0.66	854	0.76
Petrol Refining (TEL)	227	0.16	218	0.16	111	0.10	29	0.03
Alloys (Including solder)	140	0.10	110	0.08	80	0.07	48	0.04
Chemicals	105	0.07	96	0.07	80	0.07	70	0.06
Ammunition	79	0.05	67	0.05	50	0.04	44	0.04
Misc	71	0.05	64	0.05	36	0.03	24	0.02
Pipe & Sheet	34	0.02	35	0.03	28	0.02	39	0.03
Cable Sheathing	22	0.02	16	0.01	12	0.01	17	0.02
TOTAL	1,451	1.00	1,352	1.00	1,167	1.00	1,125	1.00
Average per year	120.9		112.7		97.3		93.8	

Source: U.S. Bureau of Mines

Lead-Acid Battery Recycling Rates:

With all of these trends in play and with all the lead-acid batteries in use, it is sad to note that only about 2 of every 3 lead acid batteries are currently recycled in Canada. Based upon internal NOVA data limited to the Province of Quebec, during a three year period we found that only 68% of the lead acid batteries actually were recycled. It should be noted that almost 90% of total vehicle registrations in Quebec are located within about 300 km of our plant. In more remote areas located over 500 km from a lead recycling facility, it is estimated that the recycling rate may actually fall below the 25% level.

Studies in the United States, in particular one done by Putnam Hayes & Bartlett Inc. for the U.S. EPA, produced findings which are consistent with the 3-year average that NOVA found in the province of Quebec. Table 4 is a look at the location of vehicles registered in Canada. As can be seen, 56% of the total registrations of passenger cars, trucks and buses are located in the province of Ontario and Quebec. The number of registrations in Ontario in particular has risen over 958,000 units in this 10-year period. The positive side of this concentration of vehicles and batteries in major urban areas, is that they are more likely to be recycled.

TABLE 4

PASSENGER CARS, TRUCKS & BUSES REGISTERED IN CANADA BY PROVINCE, 1977 to 1986
All data in 000's

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Nfld	175	185	194	207	204	186	193	227	247	262
PEI	60	64	67	67	67	66	69	72	74	77
N.S.	370	399	442	511	496	514	526	490	510	487
N.B.	309	330	345	353	354	361	376	391	404	414
Que.	2907	2880	3005	2999	2716	2687	2770	2783	2843	3023
Ont.	4258	4400	4247	4542	4943	4934	5045	4787	5023	5216
Man.	589	613	630	640	646	653	670	688	721	741
Sask.	646	708	670	672	680	675	682	691	689	662
Alb.	1241	1373	1485	1606	1693	1728	1737	1686	1683	1697
B.C.	1526	1598	1533	1630	1572	1998	2003	2048	2095	2145
Yukon	15	15	17	18	18	18	18	19	20	20
N.W.T.	13	14	15	15	16	17	21	20	22	19
TOTAL	12210	12577	12650	13261	13403	13838	14111	13899	14331	14762

Source: Statistics Canada

Now that we have noted some of the main trends impacting lead-acid batteries in recent years, namely more of them, the battery becoming lighter but now stable in weight and the battery lasting longer, lets attempt to quantify how much lead in lead-acid batteries is actually in use in Canada today.

Table 5 gives you some indication of the volume of lead-acid batteries in operation 1986. This data is taken directly from the study commissioned by Environment Canada, by the way. With over 22.3 million car-size batteries in use in Canada in 1986 containing 20 pounds of lead per battery, it means that over 446 million pounds of lead and about 226 million pounds of sulphuric acid were on the roads in 1986. Like all bio-chemical process, including the human body, those batteries are eventually going to die. If they all did so at one time, it would mean that over 200,000 metric tons of lead would fall out from all the hoods in Canada. At current recycling rates, almost one third or 66,000 MT of lead would not find its way to the recycling chain. If dumped in land fills or household waste dump sites, commonly referred to as garage sales, these days, that's a lot of lead to leach back into the Canadian water supply. It is obvious that the recycling of lead acid batteries has to be improved and encouraged before a large problem today becomes as even larger problem in the future.

TABLE 5

LEAD-ACID BATTERIES IN SERVICE IN CANADA DURING 1986

Class of User		Number of Users	Standard Unit Factor	Equivalent Battery Units
Passenger Cars		11,477,314	1	11,477,314
Trucks & buses	(1)	3,284,604	1.2	3,941,525
Motorcycles		430,135	0.5	215,068
Mobile Equipment		343,113	2	686,226
Tractors etc		491,749	2	983,498
Locomotives	(2)	4,169	24	100,056
Diesel Generating sites		795	2	1,590
West Coast tugs	(3)	340	24	8,160
Great Lake vessels	(4)	131	60	7,860
Fishing vessels	(5)	41,789	18	752,202
Pleasure craft	(6)	1,760,000	0.25	440,000
Sub-total; equivalent units				18,613,498
Add 20% for unidentified industrial users				3,722,700
TOTAL EQUIVALENT UNITS				22,336,198

Note:

(1)	Factor of 1.2 for pick-ups & light trucks
(2)	Factor of 24 based on 4 batteries per locomotive
(3)	Factor of 24 based on 4 batteries per tug
(4)	Factor of 60 based on 10 batteries per vessel
(5)	Factor of 18 based on 3 batteries per vessel
(6)	Factor of .25 based on 25% of craft having a battery

Source: Environment Canada study of July 1988

Now that we have had a look at the past and present, lets attempt to predict the volumes of lead and lead-acid batteries that will be in use in Canada in the future. Since a battery lasts about 50 months, we actually have the luxury of a fairly accurate window into the future. Based on exactly the same set of assumptions as Table 5, the equivalent battery units in circulation in 1981, five years prior to 1986, would have totalled less than 20 million equivalent units, but in 1991, 5 years from 1986, this will become almost 25 million equivalent units at current rates of growth.

NOVA Pb Inc.:

At this point, having the rare opportunity of holding the attention of a captive audience, I would like to elaborate upon the technology of recycling lead-acid batteries or at least, the way its done at the firm I work with, called NOVA Pb Inc., based in Montreal. NOVA Pb Inc. is Canada's largest lead recycling installation and has a capacity to produce in excess of 50,000 MT of lead a year.

Since a battery is almost exactly 50% lead, this converts to 100,000 MT of batteries per year. At 40 pounds per battery, this means NOVA Pb Inc. has the capacity to recycle about 5.5 million units per year. In complete candor, I used to describe our business and the industry that we are in, as the secondary lead industry. Every time I did so however, I received frowns and sighs when meeting people for the first time, particularly in circumstance such as this. Now, I define our business as the resource recovery business and receive a lot of smiles and implied endorsement which implies that our firm might be doing something socially or environmentally redeeming. In fact, firms such as ours are really an environmental resource in that we are providing a very essential function in removing hazardous material from the Canadian environment at no cost to the Canadian tax payer. Since there are many people in the audience charged with the responsibility to draft and implement provincial or federal legislation, I would like to highlight a phenomenon known as "environmental gridlock". In spite of good intentions, environmental regulations are all to frequently ill-conceived, mis-directed and counter productive when it comes to recycling. There are a number of examples that come to mind but in the case of recycling lead-acid batteries, environment and industry objectives, namely to recycle more batteries, are the same. The battery recycling industry regards spent batteries as their above ground mine and their consistent supply is a vital as a market for the finished end-product.

This slide is a shot of the plant itself. It is located on a 52 acre property in an industrial park along with a number of other firms in the recycling industry. The batteries are received from hundreds of suppliers from both Canada and the United States. I would like to point out for those of you who might be squeamish about the idea of Canadians importing scrap lead batteries from the U.S., that its absolutely vital for our firm to do so since sufficient volumes required to operate our facility are not economically available from Canada. According to studies by the U.S. Bureau of Mines, in order to financially support the required environmental infracture such as an integrated water treatment facility, closed-loop dust collection system and a sophisticated laboratory, the production capability of a lead recycling facility has to be fairly large. They also indicated that almost 50% of capital investment in an integrated lead-acid battery recycling complex is environmentally related. I should point out that this water treatment facility that you see in this next slide, had a capital cost of approximately 2 million dollars.

The next slide shows our battery receiving area and battery crushing operation. This operation actually provides several major functions:

1. All acid is automatically neutralized and goes to a sedimentation basin where lead particulate is filtered and removed using an elaborate system of filters and floculants. Almost all the remaining liquid is re-used internally in various washing circuits. Any effluent discharge is closely monitored and is in complete compliance with regulatory norms. In fact, all rain water which falls in the plant if returned to the environment, has a lower acid content when it leaves than when it arrived.

2. The remaining battery components are separated in lead paste or oxide, metallic lead, crushed lead grids or paste, cleaned and re-cycled plastic and hard rubber. The plastic is entirely recycled and sold to manufacturers to fabricate several products such as new battery cases.

This hard rubber or ebonite is re-used as fuel and the PVC separators are cleaned and sent to an approved land-fill site. In other words, about 37.5 out of 38 pounds of every lead-acid battery is treated or recycled.

3. The next major installation is the rotary kiln. This unit essentially smelts the lead product into a metallic lead bullion to be refined to precise customer specifications. This unit operates at temperatures around 1000^0 to 1100^0C and has a completely closed loop gas trail or dust collection system.

4. The refining is completed in a series of 100 MT kettles which refines the kiln bullion to exact client specifications. Normal soft or pure lead is 99.985% pure or better. Alloyed or antimonial lead specifications have become increasingly sophisticated in recent years as a function of the requirements of today's high performance batteries.

Lead produced at our plant frequently has to be within 1 part per million of the required client chemical analyses. It is important not to forget that the raw material for this very precise end-product is a scrap lead-acid battery.

At this point, I would like to highlight that successful recycling such as the type done by NOVA is completely dependent upon finding a market for recoverable material. Namely, separating such products from other waste or trash does not by any means guarantee their reuse. Historically, the demand for most recyclables has fluctuated with the price for virgin materials in world commodity markets. Also in many cases, such as lead, the virgin raw materials may be less expensive to produce than recycled products. The majority of lead produced in the world or in Canada for that matter, is a co-product of zinc and silver production and in many cases, gets a free ride into the market place. This price difference is often reinforced by the preferential tax or subsidy programs available to primary lead producers. In Canada for example, mining depletion allowances, flow through share programs, grants or low cost loans have all been made available to the Canadian lead mining industry in recent years whereas the Canadian lead recycling industry has received little or no support.

You will be pleased to hear that I am going to conclude this presentation today but in doing so I would like to present a number of suggestions that are intended to improve recycling rates of lead-acid batteries.

1. Firstly, I believe that Provincial and Federal government policies should provide a balance to incentive programs that currently favour virgin material an resources. If government actually supports recycling, and most say they do, they should clearly illustrate this support. Many states in the U.S. for examples, offer special credits for recycling. Oklahoma provides up to a 20% income tax credit for hazardous waste recycling. The state of Wisconsin offers sales tax exemption for some equipment and facilities. The states of New Jersey, Oregon, North-Carolina and Indiana all have other various incentives to encourage recycling.

Personally, I would like to see an incentive program that passes the benefits of consuming recycled products to the consumer level. In the precise case of recycled lead for example, I would like to see consumers of recycled lead receive a 10 - 15% credit on their purchases of recycled product to provide them with an incentive to use recycled lead instead of virgin lead.

2. Secondly, I would like to see federal, provincial and municipal programs that ban dumping lead-acid batteries with municipal house-hold waste.

3. Thirdly, consumer awareness is a must. All lead-acid batteries sold in Canada should have a sticker or stamp that encourages the consumer to recycle their battery.

4. Fourthly, I think that the retailer of lead-acid batteries should be required to have a program that accepts lead-acid batteries on a one-to-one basis of the new battery he sells and be required to handle these batteries in an environmentally sound manner.

Ultimately, consumer awareness and action are the key part of the problem but also an essential part of the solution to the recycling of any product including the recycling of the lead-acid battery. I hope that everyone who has a car here today will think of recycling their battery when it dies. Lets not await the environmental audit to highten our awareness.

Thank you very much for your time and attention.

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THE ROLE OF PLASTICS IN WASTE REDUCTION AND WASTE RECYCLING

Ron Hayter, Director of Environmental Affairs
Society of the Plastics Industry of Canada

It is a pleasure for me to be back in my hometown of Winnipeg addressing this audience so knowledgeable on the management of our societies wastes.

My father graduated with a Bachelor of Agriculture from the University of Manitoba and for part of his working life managed the Federal Government's demonstration farm at Killarney, Manitoba. In the 20's and 30's, the drought and the depression forced conservation and waste not, want not practices on everyone. I remember well, but not too fondly, the annual trips to the sewage disposal plant to pick up two or three free bags of sewage sludge which were dug into the garden. Perhaps that's still done today, although I doubt it, but it was an early experience for me in waste reduction and resource utilization. I also vividly remember the special collections for the war effort when trucks would collect cooking fat, tin and lead foil and scrap metal. We don't have a shooting war in Canada, but we certainly have a fight on our hands finding solutions to the problems of dealing with solid waste. Problems complicated by population growth, urbanization, our lifestyles and NIMBY. We are just now coming full circle from the wartime 40's with curbside collection of recyclables becoming common place across Canada. I'll talk more about how plastics fit in to these curbside or blue box programs later.

In the world of materials, Plastics are the new boy. Although plastics are well over 100 years old, large scale use has occurred only since the end of the 2nd World War. In that period of some 40 years, plastics growth has been phenomenal. To some degree it is plastics success that has drawn public attention and has given rise to the perception that the solid waste problem is plastics. That is not true of course. Perhaps a touch of paranoia on my part, but somewhat supported by the fact that paper, metal and glass are not sharing this session on waste minimization with plastics.

I mentioned earlier that plastics are the new boy. Suppose for a moment that plastics had come first. Would paper ever have been accepted when people saw that it lost its strength when wet and learned that the raw material to make paper was carbon dioxide consuming, oxygen producing trees? What about metals that rust or much heavier, breakable glass replacing plastics. An interesting scenario to think about.

But plastics did not come first and much of plastics success has come replacing traditional materials in part for the reasons just stated. What is the impact on waste when plastics replace non-plastics materials? To properly answer that question it is necessary to measure the impacts over the total life cycle of both plastics and non-plastics products.

Such a study was conducted by Midwest Research Institute for SPI, Inc. - the U.S. counterpart of SPI Canada.

Seven different container systems were examined comparing the most logical competing materials.

Half Gallon Bottle in	Polyvinyl Chloride Glass
Gallon Milk Container in	High Density Polyethylene Paperboard (polyethylene)
Gallon Produce Bag in	Low Density Polyethylene Paper
8 Ounce Dairy Tub in	Acrylonitrile Butadiene Styrene Aluminum
9 Ounce Vending Cup in	High Impact Polystyrene Paper
Gallon Oblong Container in	High Density Polyethylene Steel
Meat Tray in	Polystyrene Foam Moulded Pulp

Seven different impact categories during the products life cycle were analyzed.

Raw Materials in pounds.

Energy in BTU's.

Water in gallons.

Industrial solid waste in cubic feet.

Atmospheric Emissions in pounds.

Waterborne Wastes in pounds.

Postconsumer solid waste in cubic feet.

In the case of plastics, crude oil and natural gas raw materials are included in the energy category - the worst scenario for plastics.

The total impacts for 1 Million Containers of each system are as follows:

Summary of Total Impacts for 1 Million Containers of Each System

Container	Material	Raw Materials* (pounds)	Energy (Million Btu)	Water (Thousand gallons)	Solid Wastes (cubic feet)	Atmospheric Emissions (pounds)	Waterborne Wastes (pounds)	Postconsumer Solid Wastes (cubic feet)
Half-gallon	PVC	200.426	12.177	2.007	965	57.363	8.914	5.317
bottle	Glass	3.919.809	25.739	6.981	17.279	126.755	14.337	15.452
Gallon milk	HDPE	8.712	7.515	726	306	27.385	4.081	3.175
container	Paper	190.375	7.204	6.755	918	34.054	16.527	4.762
Gallon	LDPE	384	540	44	21	1.983	248	194
produce bag	Paper	22.542	612	532	81	3.506	1.371	536
8-Ounce	ABS	1.631	1.928	491	75	6.892	1.135	706
dairy tub	Aluminum	32.183	5.813	1.032	2.026	24.764	18.095	239
9-Ounce	HIPS	577	550	215	13	1.689	418	226
vending cup	Paper	8.315	324	304	38	1.515	740	226
Gallon oblong	HDPE	25.925	16.093	1.824	918	60.437	7.973	5.952
container	Steel	1.140.789	20.328	21.126	40.066	80.596	196.923	1.570
Meat	PS Foam	303	879	118	37	3.691	327	266
trays	Pulp	35.559	847	339	130	3.509	1.759	806

*Crude oil and natural gas raw materials are included in energy category.

Plastic	237,958	39,682	5,425	2,335	159,440	23,096	15,836
Alternate	5,349,572	60,867	37,069	60,538	274,699	249,752	23,591

In summary compared with plastics, non-plastics require:

Over 22 times more Raw Materials
1 1/2 times more Energy
Consume almost 7 times more Water
Generate 26 times more Industrial Solid Waste
Produce over 1 1/2 times more Atmospheric Emissions
Discharge almost 11 times more Waterborne Wastes
and 1 1/2 times more Post Consumer Solid Waste

Criticism of plastics contribution to waste arises frequently from examination of the waste at just the post consumer level where the differences are small.

If you look at the life cycle impacts, is there really any doubt that plastics already play a very significant role in minimizing waste?

One third of all plastics consumption is in packaging applications and much criticism has been focused on packaging as a major contributor to the waste management problem. Three studies from different parts of the world provide some interesting food for thought and opposing opinion to packaging critics.

The first is a study done at the University of Arizona and carries out a household refuse comparison between the United States and Mexico City. The study is entitled Household Garbage and the Role of Packaging. In Mexico City, where use of packaging is much less extensive than in the United States, the study shows that Mexican garbage cans are 40% heavier than in the U.S. They contain carrot tops, potato and orange peels, feet, feathers and viscera, etc. and more food which has become inedible because of inadequate refrigeration or inadequate protective packaging.

A study in the U.K. entitled Packaging Saves Waste analyzes the waste from food prepared in the home versus a central processing and packaging plant. The example studied involves 1,000 chickens. Home preparation generates 750 kg of feathers, viscera, head and feet. Central processing generates the same 750 kg of byproducts which at a central facility can be re-used for animal feed, fertilizer or other applications. The only waste resulting from the central processing operation is 7 kg of packaging needed to package the 1,000 chickens and discarded by the purchaser.

The third study was recently done in West Germany and hypothesizes the impacts that would result from eliminating plastics from packaging.

The study clearly shows that :

Tonnage of waste would increase	413%
Volume of waste would increase	256%
Energy consumption would increase	201%
Cost of packaging would increase	211%

In summarizing the information presented so far, a return to traditional materials or restrictions on plastics in favour of non-plastics would in fact increase the volumes of waste requiring disposal. In addition, much thought and study must be given to the role of packaging in solid waste. Restrictions imposed on packaging to reduce waste could produce the opposite result.

Now let's look at what is happening in plastics recycling.

As you may know, recycling of clean, segregated plastics waste is a relatively simple matter. It has been an integral part of the plastics processing industry since its inception. In many plastics manufacturing operations, scrap, trim or rejects are automatically recycled in house. In others, clean segregated scrap is sold to a well established plastics recycling industry which, in turn, resells it back to the industry for manufacturing new products.

Plastics recycling becomes a little more complicated when they become contaminated and different types of plastics are mixed together. The typical situation with household plastics waste.

One of the major barriers hampering recycling of household plastics has been collection. However, as curbside or blue box programs which will shortly cover most of Ontario and other collection infrastructures are put in place across Canada, recovery and recycling of household plastics comes closer to reality.

Right now in Ottawa, SPI, along with the Ontario Ministry of the Environment and TransOntario Plastics Recovery Inc. are collaborating on a project to improve collection efficiency and reduce the costs of collecting mixed household plastics. On truck densification utilizing granulation and compaction will be employed in this project. We are convinced that the results will show that the economics of collecting household plastics are viable where collection systems are employed for other recyclable materials as well. Final results should be available early in 1989.

Others also believe that collection and recycling of post consumer plastics makes good environmental and business sense. Last month Dow Chemical, one of the world's largest manufacturers of thermoplastic plastics resins, and Domtar, a major paper and corrugated recycler, announced a joint venture to establish a major recycling facility estimated to handle in the range of 50 million pounds annually of PET (best known as a soft drink bottle) and High Density Polyethylene used for a wide range of plastics bottles. This large scale venture will give enormous impetus to post consumer plastics recycling.

A Canadian entrepreneur has paid a deposit on a Belgian mixed plastics recycling machine called an ET1 with plans to install it in the Toronto area. This technology utilizes mixed, contaminated plastics and produces lumber or concrete like products. Although this form of recycling produces relatively low value products, there is a legitimate place for it along with more sophisticated operations which clean and separate mixed plastics into homogeneous streams of higher value.

The plastics industry in Canada is beginning the implementation of a coding system for plastics bottles and containers which will enable both consumers and recyclers to identify different plastics materials. This will be of value primarily where labour costs are not a significant factor in the overall recycling economics equation.

In Canada right now, we have a world leader in post-consumer plastics recycling. Applied Polymer Research in Edmonton, Alberta are an integrated operation manufacturing PET sheet and containers, woven and non-woven polyester textiles for roofing membranes and soil erosion and flower pots from HDPE. APR's raw materials are used plastic soft drink bottles and other household containers. APR's technology has now been licensed in several other countries around the world.

In Quebec, Les Industries Transplastek has a facility for cleaning and separating mixed household plastics into the major resin types. Some is used internally for their own manufacturing operations with the balance sold as raw material to other plastics processors.

In the United States, the Centre for Plastics Recycling Research funded jointly by government and industry operates a research facility and pilot plant to address and solve the problems associated with recycling post consumer plastics.

On October 11 I participated in a one-day workshop sponsored by ASTM to begin to develop standards for recycled plastics materials.

As you can see much has been happening in plastics recycling and much more will happen in the near future. I believe that within the next year or two collection and recycling of household plastics will become a reality in most communities with multi-material curbside or equivalent collection infrastructures.

There is, however, one very real threat to this vision of expanded post consumer plastics recycling.

The perception exists now and is growing that the answer to the problem of plastics in the solid waste stream is degradeability. The technology to make plastics either photodegradeable or biodegradeable is now well established. Although degradeability is a useful tool for very specific and very carefully thought through applications, widespread use of these technologies have the potential to stop post consumer plastics recycling, now becoming a reality, dead in its tracks.

Imagine if you will that some unknown portion of waste plastics collected for recycling contain either photo or biodegradeable additives. The physical properties and life expectancy of new products then become unpredictable and markets for recycled plastics will dwindle away.

In my view, recycling of plastics is far more desirable than to make them degradeable in broad applications where the inherent resource as a material or even as energy is totally lost and wasted.

I urge all of you in positions of responsibility to consider very carefully the negative impact on plastics recycling which will result from the adoption of degradeability as a general solution to the solid waste problem.

AN APPROACH FOR CONDUCTING WASTE MINIMIZATION AUDITS

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As environmental audit programs have evolved over the past few years, companies have very often changed their initial focus to reflect findings of baseline audits. More often than not this has meant incorporating a significant waste minimization component into the program. There have been several reasons for this development:

- Historical Noncompliance. Many of the non-compliance findings in the early audits have been a result of poor waste management practices.
- Regulatory Requirements. Hazardous waste manifests require generators to certify that they "have a program in place to reduce the volume and toxicity of waste generated. . ."
- Regulatory Trends. Recent federal and state rules are prohibiting the land disposal of a wide variety of hazardous wastes, thereby reducing the disposal options available.
- Economics. Waste disposal is becoming considerably more expensive.

Successful waste minimization can mean having to meet less stringent regulatory standards, not having to rely on other companies to ultimately dispose of wastes, and paying substantially less for waste disposal. Accomplishment of these goals can do much to improve compliance at individual plants and minimize the liabilities of the corporation.

Conducting waste minimization audits typically can be accomplished in two ways. They can be included as part of the standard audit process or the company can create waste minimization "hit squads", using staff with specialties in manufacturing and process control, who travel from plant to plant attacking the specific problem of waste minimization. The first approach is less resource intensive but less likely to achieve significant reductions.

Either approach can be successful but one needs to be aware of the distinctions between the more traditional audit approach and what is required to complete a waste minimization audit. Historically, environmental audits have been designed to verify that adequate compliance assurance systems (organizational and physical) are in place at the operating facilities. Therefore, audits are not meant to substitute for good, effective site environmental management, which is required day-in and day-out, not simply when the audit team is on site.

Waste minimization audits differ in that more is involved than simply verification. The audit team is typically being asked to work with the site staff to review waste generation operations, analyze the potential for waste reductions, and to jointly identify solutions to the high-priority problem streams. In this way the audit team is being asked to become more intimately involved in the operations of the facility.

Of course, these differences in waste minimization audits bring with them some advantages and disadvantages. On the plus side, the audit can be seen as more helpful than otherwise might be the case. However, it is also more intrusive. Thus, the auditors must be very diplomatic in their investigations. Good technical skills will accomplish only so much.

The objective of a waste minimization audit generally is to reduce the volume and/or toxicity of wastes. However, meeting this commendable objective is fraught with frustrations. Auditors should be aware of the following roadblocks in particular:

- Waste minimization audits are very site specific. So, it is often very difficult to apply the lessons of the past to the case at hand.
- Like many things in life, waste minimization suffers from the 90/10 rule. Ninety percent of the reductions are often achieved with the first ten percent of the effort. Thus, it becomes exponentially more difficult to attain significant reductions as time goes on.
- Waste minimization can be as much an organizational issue as a technical one. Seemingly simple steps recommended by the audit team will result in scores of responses by purchasing, manufacturing, and the sales force as to why they're impossible to implement.

Notwithstanding these limitations, waste minimization audits can be a worthwhile exercise. In general the analytical approach is similar to conducting a more routine environmental audit. The audit team reviews the available written records, interviews key site environmental and operational staff, and inspects the plant's facilities. In conducting this exercise, the auditors are generally attempting to identify the following:

- The "devil's" chemicals. In most manufacturing there will be a few chemicals that are extremely toxic and/or troublesome (e.g., phosgene). A waste audit's goal should be to identify where these chemicals are used and what by-products or waste products their use generates.

- High volume waste streams. The 90/10 rule often applies here as well. In many cases, ten percent of the waste streams generate ninety percent of the volume. Investigating these waste streams first is likely to result in the most cost-effective reductions.

- Highly regulated wastes. Wastes such as dioxins, PCB's, chlorinated solvents, and RCRA acutely hazardous wastes should receive considerable attention during the audit. If for no other reason they should receive this attention because, in many cases, they have become "political" wastes.

- Land disposed wastes. Wastes that are land disposed present special problems for generators. Strict, joint, and several liability tenets suggest that the generator maintains some liability even when indemnified by a disposal company.

Identifying waste streams that fall into the classes presented above will help set priorities for the audit, which by its nature is a time and resource limited exercise. And there are ways to use readily available data to indeed identify these streams. Some of the more common are listed below:

- Material Safety Data Sheets
- RCRA Annual of Biennial Reports
- RCRA Hazardous Waste Manifests
- The RCRA list of Acutely Hazardous Substances
- SARA Title III Lists, Reports and Submissions
- State Air Toxics Lists
- EPA Clean Air Act NESHAPS Chemicals and Candidate Chemicals
- Air Emissions and Asbestos Inventories
- PCB Electrical Equipment Inventories
- EPA Clean Water Act Priority Pollutants
- Waste Disposal Companies' Records and Invoices
- Sludge Disposal Records
- Records of Pollution Control Equipment and Operations and Maintenance Expenditures

Once these sources are reviewed, each of the priority waste streams can be investigated for its reduction potential. It should be clear from the nature of the sources that the waste minimization audit must be more encompassing than simply a review of RCRA generated hazardous wastes. Wastewaters, air emissions and other sources of toxic releases must be considered as well.

Evaluating the reduction potential involves analyzing each waste stream against a number of options. Although it is difficult to make generic suggestions on possible waste minimization strategies, a list of the more common reduction solutions is presented in the exhibit on the following two pages. These solutions generally fall into the control strategies listed below:

- Material Conservation. Until the last few years there has been little incentive to conserve many raw materials. Yet, better management and/or more careful use of paints, solvents, and maintenance chemicals could significantly reduce chemicals being emitted through vents, washed down the drains, or sent out for disposal. Vehicle and machinery maintenance should be scheduled at proper, but not overly conservative, intervals. Where process vessels are used to manufacture different products, line management should schedule runs such that chemical cleaning of the vessels is minimized.

- Material Substitution. Significant inroads have been made by many companies using this strategy. Typical substitutions include: fiberglass for asbestos and urea formaldehyde insulation, non-chlorinated for chlorinated solvents, and water-based for solvent-based coatings and paints.

- Inventory Management. Even at the risk of displeasing the discount-minded purchasing agent, many companies are buying chemicals in much smaller quantities. Where at all possible five and ten gallon pails are often preferred to the tanker truck or ubiquitous 55 gallon drum. In fact one company has a policy that 55 gallon drums can be purchased on an exception basis only. Companies are also becoming more fastidious about requiring a first-in, first-out inventory policy for chemicals. This minimizes the potential for old drums to accumulate and deteriorate in the rear of a warehouse.

- Recycling/Segregation. These two approaches fit hand-in-glove. For it is often that materials cannot be recycled because they have not been segregated properly. Used oils are occasionally so contaminated with solvents that they are not reclaimable. Where wastes must be generated it is often prudent to search for a waste exchange; for one man's waste might be another man's raw material. Some companies use their corporate environmental department as a clearing house in this regard. The departments search for both intra-company and commercial users or buyers of excess inventory, past-shelf-life materials, or recoverable wastes.

- Process Modifications. Significant gains can be achieved using this strategy. Some potential approaches were mentioned above (e.g., the use of water-based coatings). Other waste reductions can be attained by looking closely at the manufacturing process with trained eyes. One company was able to develop a sophisticated plastics extrusion process that allowed them to fabricate composite conduit directly, as opposed to fabricating

POTENTIAL OPPORTUNITIES FOR WASTE MINIMIZATION

(1) Use of non-chlorinated solvents for cleaning (e.g., Simple Green)

(2) Use of water-based coatings and paints

(3) Purchase-by-exception for 55 gallon drums

(4) Purchase-by-exception for toxic ("the devil's") chemicals

(5) Emphasis on maintenance chemicals as well as process chemicals

(6) Set vessel run schedules to minimize the need for frequent cleanouts

(7) First-in, first-out inventory control

(8) Minimizing the cross-contamination of used oil with solvents

(9) Internal clearing-house function for excess inventory, old chemicals, and recoverable wastes

(10) Revising processes (e.g., using composite plastics extrusion manufacturing versus simple extrusion and adhesion eliminates the generation of adhesive wastes)

(11) Improved housekeeping (e.g., keeping lids in degreasers, minimizing spills during materials transfer and dispensing)

(12) Use of oil-water separators in sewer systems

(13) Requiring R&D staff to purchase chemicals in small quantities, to not accept salesmen samples indiscriminately, and to work with vendors with return policies

(14) Training R&D staff to be aware of environmental consequences of design

(15) Requiring all capital improvements to be signed-off by corporate environmental department

(16) Requiring secondary containment at all fill and dispensing areas (e.g., tank farm manifolds, underground storage tank fill ports)

(17) Segregating chemical storage from waste storage; isolating solid wastes from hazardous wastes.

(18) Evaluating the integrity of all floor drains and septic tank systems

(19) Using the full service capabilities of reputable waste disposal contractors (e.g., Chemical Waste Management's Waste Minimization Service)

(20) Above all, making it a real corporate policy! Institute an incentive program for plant managers; they will make it happen!

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two separate pieces and binding them together with adhesive. The new process was especially cost-effective when the cost of waste-adhesive disposal was factored into the analysis.

- Waste Treatment and Destruction. The waste minimization strategy of last resort. If all else fails do your best to detoxify or destroy the wastes. Land disposal, or long term storage if you will, is an extremely questionable approach in this day of Superfund-mandated cleanups. Of course, some wastes and treatment residuals have no other alternative presently. Yet, many companies have developed a policy that land disposal of any wastes will be allowed on an exception basis only. Biological chemical, and physical treatment technologies are evolving rapidly, so it is likely that fewer and fewer waste streams will become exceptions under this type of policy.

In sum, waste minimization audits are not unlike any analytical exercise. First, high priority waste streams are identified through a review of documents, discussions with site staff, and an inspection of the site. These streams are typically ranked and analyzed for potential reduction strategies, such as material substitution and process modifications. Where potential strategies are identified, a detailed study is made of the costs and benefits. This study includes the concerns of purchasing, manufacturing, and sales. That is, recommended changes must incorporate use of equivalent and readily available materials and processes, which do not materially affect the quality of the product or the cost of its manufacture, including the cost of waste disposal.

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THE ROLE OF WASTE EXCHANGE IN WASTE MINIMIZATION

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INTRODUCTION

In this paper, we will discuss the role of Waste Exchange in the overall move to minimize industrial wastes. We will do so by considering the following:

- The waste management hierarchy
- The rationale for moving toward waste minimization
- How the Waste Exchange fits
- History of the CWME
- Performance of the CWME
- Future directions for waste exchange

WASTE MANAGEMENT HIERARCHY

We believe there is a definite hierarchy of approaches to industrial waste management, and this is shown below, going from most to least desirable options:

WASTE MANAGEMENT HIERARCHY

Waste Abatement	Don't Make It
Waste Minimization	If you have to make it, minimize its volume and toxicity
Waste Reuse	See if someone else can use it
Waste Recycle	If it can't be used as is, reclaim as much as possible that is useful
Waste Treatment	Treat what can't be reclaimed to render it safe
Waste Disposal	Dispose of residues to air, water or land

Our definition of waste reduction would include all the first four approaches, abatement, minimization, reuse and recycle. Others restrict the definition of waste reduction to what we have called abatement. We strongly disagree with this narrow definition, as we believe that the hierarchy is a continuum and that any movement vertically upwards by a company should be encouraged, as it will achieve the overall goal of lessening the impact of industrial waste on the environment.

How closely to the ultimate aim of not making the waste each industrial waste management problem can be moved is dependent both on the physical/chemical nature of the problem, size of stream, etc., and on the geographic location of the business. It is much easier, for example, for companies in Southern Ontario to find recyclers of wastes than is the case in Newfoundland or Saskatchewan.

Some examples of industrial waste reduction approaches are given in Figure 1.

	EXAMPLES
WASTE ABATEMENT Substitution of a new low-waste primary industrial process for an old process to eliminate or drastically reduce the quantity of waste produced	- Replacement of sulphuric acid in steel pickling with hydrochloric acid - Replacement of liquid paints by powder coatings - Replacement of solvent based adhesives with water based adhesives
WASTE MINIMIZATION The reduction of the quantity of waste through good housekeeping practices or by the application of concentration technologies. Also the reduction in the degree of hazard of waste through simple in-plant treatment	- Separation of waste streams to permit recovery - Application of countercurrent rinsing to minimize volume discharge - Neutralization of wastes and precipitation of smaller volume sludges - Fixing leaky taps and nozzles
WASTE REUSE The direct reuse of a waste stream, as is, or with a very minor modification	- Reuse of surplus or salvage chemicals - Use of blast furnace slag as aggregate - Use of solvents from electronics industry in paints manufacture - Use of refinery spent caustic in pulping wood - Use of oil sludges in asphalt manufacturing - Use of electronic circuit manufacturing plating baths in regular plating shops
WASTE RECYCLE The reclamation of value from waste streams through the application of reprocessing technologies such as distillation, etc.	- Oil rerefining - Solvent distillation - Recovery of iron salts from pickle liquor - Recovery of heavy metals from sludges - Recovery and reuse of spent foundry sands - Recovery of scrap metal - Landfarming of organic wastes - Regeneration and reuse of activated carbon - Recycling of grease and fats to renderers

FIGURE 1 - WASTE REDUCTION APPROACHES

RATIONALE FOR WASTE MINIMIZATION

The rationale for companies moving up the waste management hierarchy toward abatement, minimization, reuse and recycle is that it makes good business sense to do so. There are three factors which are causing this:

- Legislation
- Economics
- Company Image

Legislation is effecting changes in waste management practices, both directly and indirectly. Sewer use discharge limits and regulations, such as Ontario's MISA programme, are directly legislating what a company can dispose to the environment. The indirect effect of tough legislation on industrial waste management is to increase the costs of the treatment and disposal options to the point where previously uneconomic waste reduction alternatives become very attractive.

Some U.S. States are considering legislation directly regulating waste reduction. Our feeling is that this should be approached with great caution to ensure that laws are not passed which are unenforceable. Better to drive the movement to waste reduction indirectly than to have unenforceable direct legislation.

Economics is by far the most influential factor in a company's move toward waste reduction. Rapidly escalating disposal fees for both hazardous and non-hazardous waste are getting the attention of senior management in companies, and encouraging them to look at alternatives. Industry has always worked to minimize wasting raw materials through yield improvement. Now the double penalty of wasted raw materials and high cost for the disposal of that waste is really focussing attention.

In Ontario, landfill tipping fees for non-hazardous waste have escalated to $50 in the Golden Horseshoe area, Toronto, Halton and Peel. These costs are likely to double or triple over the next few years.

The cost for hazardous waste disposal is also rising at an equally rapid rate, as increasingly stringent regulations are enforced and provision for long-term care of disposal sites are required.

Many companies are responding very successfully to the challenge of improving the economics of waste management by moving their practices up the waste management hierarchy. A number of large companies told stories of these successes at a series of 4 meetings held at Woods Hole, Mass., in 1985, 1986, 1987 and 1988(1). Pollution Probe published a book, 'Profit from Pollution Prevention'(2), describing some successful case studies from smaller companies as well as some large ones. It is, perhaps, wrong to single out specific companies, but 3M have been very prominently involved(3) in waste reduction for a number of years. 3M were among the first to recognize the benefits of viewing waste reduction in a positive light. They established their 3 "P"s (Pollution Prevention Pays) programme and were willing to talk publicly about their achievements. They continue to be very innovative in implementing waste reduction which, in every case, has been economically beneficial to 3M.

Discussing 3M leads to the final factor in encouraging waste reduction: company image. 3M have taken their 3Ps programme and used it to enhance their already well established image as an innovative firm.

Other companies are very concerned with the potential negative publicity associated with improper waste treatment and disposal, and any long-term negative effects of such activities. Companies consist of people who live in neighbourhoods around their plants. They do not want an unhealthy environment for their families any more than families not associated with the plant. Waste minimization activities thus enhance a company as a good neighbour doing its best to conserve resources and minimize negative impacts on the local environment.

WHAT IS THE ROLE OF WASTE EXCHANGE

The major role of Waste Exchanges is to facilitate waste reuse by matching potential users of wastes with generators of wastes.

The concept of waste exchange is based on the assumption that "one man's garbage may be another man's gold" (or, in the case of used X-ray film, another man's silver!). For the "other man" or company to take advantage of the "golden garbage", he must first know that it exists.

Waste reuse opportunities are being very actively pursued, particularly within industry sectors. Industry specific experts are very much aware, these days, of opportunities within their own industry sector for the reuse of wastes. Defining the needs and potential waste reuse opportunities in all of the other sectors of the Canadian Industry is a much more difficult challenge and not one which many industry waste experts can afford to meet.

Waste Exchanges try to bridge this information gap. By listing available industrial waste streams and waste streams wanted as substitute raw materials in a regular publication and distributing this to all industry sectors, one industry sector is made aware of the wastes available from and wanted by other sectors.

Even for the most knowledgeable of engineers who feels that he does understand all industry sectors and their potential for supplying or utilizing wastes, it is unlikely that he could readily identify specific companies, who are not only able to use his waste or supply him with waste, but are also interested in doing so. Until a specific waste generator and a specific potential user for that waste are identified, all one has is a theoretical awareness that Waste A from Industry X could potentially be used in Process B of Industry Y.

While the major role of waste exchange is to facilitate reuse opportunities, what actually happens is that the Waste Exchange ends up acting as an "information clearinghouse" on all aspects of waste management. We promote waste abatement and waste minimization activities, particularly minimization, to improve the "exchangeability" of wastes, e.g. segregation of different wastes to improve purity, or dewatering to improve concentration of valuable components.

This information transfer role, which we recognize we share with many others, is, we believe, a most important activity of a Waste Exchange. A U.S. National Academy of Science Study on Waste Reduction(4) concluded that a major barrier to increased industrial waste reduction was insufficient information transfer on available options, particularly for small to medium sized companies.

HISTORY OF WASTE EXCHANGE IN CANADA

The Canadian Waste Materials Exchange was established in 1978. Like the Canadian Waste Management Conference, we, too, are celebrating our 10th anniversary. Even before that time, some activity was going on in Canada. Ontario Research Foundation undertook an extensive study(5), sponsored by Environment Canada, of Waste Exchanges existing in 1976. At that time, two initiatives were in place in Canada. In Ontario, the Ministry of Industry and Tourism were running a Waste Exchange as part of another publication which they mailed to Ontario industry. Canadian Chemical Processing Magazine was encouraging readers to use their "letters to the Editor section" to describe wastes which were available.

The Canadian Waste Materials Exchange was established as a national programme serving all of Canada. It was established as an informational exchange rather than a more active "waste brokerage", and was sponsored for its first two years of operation entirely by Environment Canada.

Six bulletins per year have been issued since its establishment. The bulletins are divided into 3 sections: confidential listings of Available and Wanted Wastes, and a non-confidential section of Services Available.

Since 1980, we have tried to get industry to pay for the operation of the CWME. We only managed to generate 30-40% of our operating funds from industrial participants. It is interesting that the U.K. Waste Exchange also found that they could only generate about 30% of their required funding from industry. We are now funded by a mixture of sources:

Industry	approximately 30%
Federal Government	approximately 30%
Provincial Governments	approximately 40%

It seems appropriate that these three funding sources are supporting the CWME since all three have responsibilities for the safe management of industrial waste in Canada.

Since 1984, a number of regional Exchanges have been established in Canada, all of which are linked to the CWME. Provincial Exchanges exist in:

- B.C.
- Alberta
- Manitoba
- Ontario

The B.C. Exchange is being operated by the Recycling Council of British Columbia with some government funding. The Alberta Waste Exchange is operated by the Alberta Research Council and sponsored by Environment Alberta. The Manitoba Waste Exchange is operated by the Biomass Institute and is funded by the Manitoba Hazardous Waste Management Corporation. The Ontario Waste Exchange is operated by Ontario Research Foundation and is funded jointly by Ontario Waste Management Corporation and the Ontario Ministry of the Environment.

In Ontario, there are presently 14 municipalities and/or regional governments that operate their own Industrial Waste Reduction Programmes. These programmes have been developed primarily in response to the landfill crisis situation in Southern Ontario, and serve to complement the existing municipal recycling programmes. Through these programmes, wastes are identified and, where markets are not readily available, referred to the CWME for listing.

At the Ontario Waste Exchange we do not publish our own catalogues. We very actively pursue waste exchange opportunities by phoning likely users or suppliers and trying to make matches. Again, non-exchanged streams are referred to CWME for listing.

PERFORMANCE OF THE CANADIAN WASTE MATERIALS EXCHANGE

We have tried, on a continuing basis, to analyze the performance of the Canadian Waste Materials Exchange to determine the effectiveness of the programme. Figure 2 summarizes the operation from January, 1978, to March 31, 1988. 3,500 companies participate in the Waste Exchange programme. While we have never sought foreign participants, we have a number of U.S. companies using the CWME and even a few in Japan, India and the Phillipines.

	January 1, 1978, to March 31, 1988
Number of Participating Companies	3,500
Number of Wastes Listed	2,887
Number of Wastes Enquired About	2,574 (89.2% of listings)
Number of Enquiries	20,842 (7.2 per listing)
Number of Wastes Transferred	539 (18.7% of listings)
Annual Tonnage of Wastes Transferred	320,500 tons
Value of Wastes Transferred	$11.8 million/year

FIGURE 2 - Summary of the Operation of the Canadian Waste Materials Exchange

We have listed a total of 2,887 wastes. 89% of those wastes were of sufficient interest to generate at least one enquiry. The average number of enquiries per listing is about 7.2. The number of waste transfers we have recorded is 539 or 19% of the listings on a numbers basis. Because we do not get involved in the negotiations between two companies considering an exchange, we have to rely on one of the companies letting us know that a transfer has occurred. This is not always done as rapidly as we would like.

The final two figures in Figure 2 are, of necessity, approximations. We have attempted to estimate the annual tonnage of material transferred in those 539 recorded exchanges. Our best estimate is 320,000 tons. The "replacement" value of that 320,000 tons has been estimated at about $11.8 million/year. This figure is computed by estimating the value of the raw material which the waste has replaced. Conservative estimates have been used throughout.

This replacement value estimate can be readily criticized, and it should be used with caution. However, we believe it does give us a reasonable estimate of an order of magnitude estimate of the economic impact of the Canadian Waste Materials Exchange. We further believe that this performance justifies the annual cost of operating the CWME of approximately $50,000.

Figure 3 shows a breakdown of tonnages of wastes exchanged by Category and is also divided into ongoing waste streams and one time wastes. As can be seen, two-thirds of the exchanges involve ongoing waste streams. Assuming that most items in categories 1-6 would be considered hazardous waste, the division between hazardous and non-hazardous waste is about 50:50.

To March 31, 1988

Category	Ongoing Exchanges tons/year	One-Time Exchanges tons	Total
1. Organic Chemicals	1,191.8	1,037.9	2,229.7
2. Oils, Fats and Waxes	33,629.5	91,803.0	125,432.5
3. Acids	1,875.0	10,011.1	11,886.1
4. Alkalis	13,322.0	63.1	13,385.1
5. Other Inorganic Chemicals	2,813.2	483.8	3,297.0
6. Metals & Metal Sludges	15,768.0	477.0	16,245.0
7. Plastics	1,315.9	472.3	1,788.2
8. Textiles, Leather & Rubber	5,752.1	23.0	5,775.1
9. Wood & Paper Products	81,897.0	620.0	82,517.0
10. Miscellaneous	56,872.0	1,029.0	57,901.0
11. Lab Chemicals	-	0.1	0.1
	214,436.5	106,020.2	320,456.8

FIGURE 3 - SUMMARY OF WASTE QUANTITIES EXCHANGED BY CATEGORY

Figure 4 shows the distance travelled by the 539 recorded wastes which have been exchanged. As might be anticipated, a large number of wastes travelled short distances, < 50 miles. Significant numbers of wastes, however, have travelled over 200 miles and some have even exceeded 1,000 miles.

To March 31, 1988

		% of Those Stating Distance
< 50 miles	154	35.8
50 - 100 miles	42	9.7
100 - 200 miles	42	9.7
200 - 500 miles	149	34.6
500 - 1000 miles	19	4.4
> 1000 miles	25	5.8
Did Not State	108	
	539	100.0

FIGURE 4 - ANALYSIS OF DISTANCE TRAVELLED BY WASTES TRANSFERRED

FUTURE DIRECTIONS FOR WASTE EXCHANGE

Looking forward to the next ten years, what new initiatives or changes in emphasis might we expect from Waste Exchanges

The Canadian Council of Resource and Environment Ministers (CCREM) commissioned a study of Waste Exchange in Canada which was carried out by Acres International of Vancouver. This independent study of existing Waste Exchanges will recommend ways in which waste exchange in Canada can be made even more effective. It should also address the question of ongoing sources of funding for waste exchange. Unfortunately, at the time of writing this paper, we had not seen the report of the study, so we are unable to discuss any of its recommendations.

There are a number of areas with which we would like to get more involved. Obviously, the basic role of the Waste Exchange is going to remain matching waste generators with potential waste users. There are initiatives which we are already beginning to work on which we hope will facilitate our fundamental role and get us more involved in stimulating companies to be involved in other waste reduction options. A number of these initiatives are being undertaken by the Ontario Waste Exchange, which has the greatest level of staffing of any Exchange in Canada, at about 1.3 person years per year. Some examples are discussed briefly below:

Links to U.S. Exchanges

All of the Canadian Exchanges are establishing and maintaining links with U.S. Waste Exchanges. We all now share a common listing form and waste categorization. Listings are shared back and forth between Exchanges, thus broadening the potential for finding users/suppliers of waste. These links were further strengthened in May of this year when we hosted the Fifth North American Conference on Waste Exchange in Canada for the first time. These linkages also provide opportunities to exchange ideas and case histories on what can and cannot be done with particular wastes. We anticipate these links will continue to grow in the decade ahead.

Computer Access to Waste Exchange Listings

Most North American Waste Exchanges are now moving toward putting their listing information onto computer data bases. The Northeast Waste Exchange in New York now has their system set up to allow access by others to the data. This should speed up the rate at which new listings are available to potential users. We are moving in the same direction but we want to be sure that confidentiality is maintained for those listers who are particularly concerned about security. We still feel that, even with on-line data accessibility, the publication of a bulletin is a good way to stimulate continuing interest in the Waste Exchange. Without this reminder every two months, we are concerned that people may not continue to access the data base on a long-term basis.

Research

A number of waste streams generate a lot of interest, but do not exchange. In about 50% of the cases, we are told that the reasons are technical incompatibilities. Ontario Waste Management Corporation, as part of their sponsorship of the Ontario Waste Exchange, have supported a series of small research programmes designed to investigate modifications to such waste streams to make them more exchangeable. We believe that this should be an increasing activity for Waste Exchanges or others in the decade ahead.

New Recycling Businesses

In a number of other cases, the reasons for wastes not exchanging are not entirely technical, or do not require research to generate a solution. These are cases where quantities are insufficient or simple physical changes might be required to make the materials reusable. We are increasingly getting involved with entrepreneurs wanting to set up businesses to act as "Middlemen" for waste exchange. A simple example is in wood waste. Industry can certainly use an alternative solid fuel, and there is plenty of wood waste available. Its diverse distribution and physical format presents a barrier to its reuse. We are currently working with an entrepreneur in Ontario who will collect and homogenize wood waste and market it as a fuel. The role of the Waste Exchange in this is to help identify potential suppliers and users, and, further, to help with identifying government funding programmes and any regulatory requirements for new recycling businesses.

Technical Assistance

We would like to get more involved in providing technical assistance to industry on all aspects of waste management. This will be through plant visits, provision of information over the phone, literature reviews, seminars and workshops. We are increasingly more effective at providing this type of information transfer with each year of experience and new contacts that we make. We recognize that others, such as OWMC, Manitoba Hazardous Waste Management Corporation, Ministry of the Environment Ontario, and many other provincial ministries are also providing similar assistance. At the present time, however, the need for such information transfer to industry is so great that there cannot be too many potential sources. We stay in as close contact as possible with everyone interested in waste reduction.

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"SOLID WASTE DISPOSAL IN THE NORTHWEST TERRITORIES"

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Paper unavailable at time of printing

SESSION IIIA "WASTE MANAGEMENT OPTIONS"

WEDNESDAY, OCTOBER 26, 1988, 9:20 a.m.

HANDLING, TREATMENT AND DISPOSAL OF WASTES IN HEALTH CARE FACILITIES

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Introduction

A diverse range of waste types are generated by hospitals. It is important to handle these chemical, biological, and institutional wastes in an appropriate manner so that hospital personnel are protected. The staff of the Manitoba Department of Environment and Workplace Safety and Health work with health facility personnel to ensure proper handling and disposal of these substances.

Background

Hospitals and other Health Care facilities are significant contributors to the environmental waste streams. The diversity of hospital functions has resulted in the production of many waste materials which require special methods of handling so that hospital workers are protected and disposal methods are environmentally acceptable. These special procedures are required when hospital wastes are handled due to their potentially hazardous nature.

To ensure proper handling and disposal of hospital waste, the staff of the Manitoba Department of Environment and Workplace Safety and Health have several acts and regulations which can be directly applied to health care management. The Environmental Management Division has direct involvement with hospitals for the enforcement of The Dangerous Goods Handling and Transportation Act and the Manitoba Incinerator Regulation under the Environment Act. The Workplace Safety and Health Act and the Workplace Hazardous Material Information System Regulation are enforced by the Workplace Safety and Health Division to ensure personal safety of workers.

Most hospital waste is addressed under the general guidelines of the CSA Standard "Handling of Waste Materials Within Health Care Facilities". This document addresses segregation, collection, movement and storage of waste materials within health care facilities. The ultimate disposal methods are subject to governmental regulatory control. The disposal procedures include on site incineration or removal from the health care facility.

Hospital Waste

All waste materials generated in a health care facility can be segregated into the following categories:

1) human/animal anatomical waste,
2) infectious non anatomical waste,
3) sharps and similar waste,
4) chemical/pharmaceutical waste,
5) radioactive waste,
6) pressurized container waste,
7) general waste.

All waste handled must be segregated at the source and be readily identified by workers. The CSA Standard Z317.1D-88 promotes the use of labels and color coded containers which facilitate in house control and the safe movement of waste. The specifications of container storage areas and waste holding apparatus are identified in this standard.

1) Human/Animal Anatomical Waste

Human anatomical waste consists of tissues, organs, body parts and the products of conception. The material is to be handled within the hospital in a red coded bag and moved directly for storage and disposal. Appropriate disposal methods include incineration. Some Manitoba hospitals have this material handled by a funeral home.

Animal anatomical waste is a waste which is generated within hospitals that have animal research sections and in teaching hospitals. This material can be incinerated on site or transferred to a veterinary crematorium for disposal.

2) Infectious Non Anatomical Waste

This waste category is any waste which contains viable micro organisms which are capable of transmitting disease. Waste from communicable disease wards, laboratory wastes and wastes from infected patients are all sources of this type of waste. The CSA standard requires the waste to be contained in a yellow coded bag. Disposal methods include incineration, autoclaving and treatment, and then disposal.

3) Sharps and Similar Wastes

Needles, blades, vials and syringes all make up this waste category. This material is usually placed in a hard container which resists puncturing. The needles, etc. must be rendered useless prior to disposal. The best method of disposal is on site incineration. In some small health care centres this waste is burned at the local landfill under supervision of hospital personnel.

4) Chemical/Pharmaceutical Waste

Chemical wastes are to be handled and disposed of in accordance with The Dangerous Goods Handling and Transportation Act and local legislation. Pharmaceutical wastes include wastes which are outdated, contaminated or residual. This waste is usually controlled under the direction of the Head of Pharmacy. Disposal procedures of this material are usually available from the manufacturer. Incineration and chemical deactivation are the accepted methods.

5) Radioactive Waste

The Atomic Energy Control Act regulates the handling and disposal of all radioactive wastes.

6) Pressurized Container Waste

This type of waste is usually placed with the general waste, but must not be incinerated.

7) General Waste

The total waste generated at a large hospital will include general waste which can contain kitchen waste, shop waste, institutional waste, glass waste and miscellaneous waste. This waste, not in contact with infectious or hazardous material, can be handled and disposed of by landfill or in an appropriate incinerator without any special handling or treatment.

Manitoba Hospitals

Thirty five hospitals in Manitoba presently use incineration as the preferred method of disposal. Multichamber incinerators are fitted with secondary burners to ensure a high enough heat to meet minimum pathological incinerator requirements of 1400°F. Most recently installed incinerators are of the controlled air design with the capability of temperatures in excess of 1800°F.

The capacities of these incinerators are matched to the hospitals and range in size from 50 cubic feet to 1000 cubic feet capacity. The hospitals provide their own burn schedules which may require incinerator operations as often as once per day or as little as once per week, depending on the quantity of waste producted by the hospital.

Most hospitals remove kitchen and cafeteria waste for off site disposal.

Manitoba Health Services Commission has been supplying funds for hospital incinerators based on the following requirements:

1. Hospitals must have a birth delivery ward,
2. Hospitals must maintain an active laboratory,
3. Hospitals must maintain operating facilities,
4. The hospital must be undergoing a major expansion or construction.

If these criteria are met a suitably sized Pathological Incinerator will be supplied to the hospital.

If an incinerator is not on site then the hospital must use the best available disposal method.

Environmental Management Division

The Environmental Management Division is involved with the hospitals and health care facilities by enforcing The Dangerous Goods Handling and Transportation Act (DGH&T) and associated regulations including the Manitoba Regulation 91/88R pertaining to incinerators.

The intent of the DGH&T Act is to identify waste generators by requiring them to complete the Generator Registration Report Form. The information contained will include the type of waste generated, quantity and the specified method of handling (e.g. incineration, storage, etc.). This information will be reviewed and a Provincial Registration Number will be issued.

The method of disposal is also scrutinized by the DGH&T Act. If a carrier is involved in transporting hazardous material, then the carrier must register with the Department and comply with Regulation 175/87. If the disposal is on site, the method of disposal must be registered.

Hospitals carrying out on site incineration are regulated by the Manitoba Incinerator Regulation 91/88R and also must complete an approval form for on site Hazardous Waste Incineration. The completed registration form is forwarded to Environment Management Division for approval. The information contained on the form includes plans, specifications, operator, types of waste to be incinerated, incinerator design, burner stack dimensions, type of air pollution control equipment, etc.

This information allows approvals for wastes types and quantities to be monitored to ultimate disposal.

The Manitoba Incinerator Regulation 91/88R is a regulation under the

Environment Act which addresses the air pollution emissions from incinerators in Manitoba. Registration of incinerators allow the Air Pollution Control Section to collect information on incinerator types and set maximum emission standards.

Where waste is transported off site, the carrier, generator and receiver must all be registered to ensure proper disposal from originating source.

Areas of Concern

With increased awareness of hazardous wastes, the hospitals have been subject to investigation by a number of agencies. The Canadian Council of Resource and Environment Ministers (CCREM) is presently collecting information to develop a code of practice which may be forwarded to hospital administration. The Ontario Ministry of the Environment established guidelines for the Handling and Disposal of Biomedical Wastes from health care facilities and laboratories in 1986. Many sections of these guidelines have been applied by Manitoba Hospital Administrations.

The quantities of waste generated in hospitals have significantly increased proportionately with the concern about the AIDS disease. The numbers of disposable gloves, gowns, masks, etc. have increased dramatically over the last few years. These larger quantities have posed a problem because of the volume of waste generated plus the high halogen content of these materials. Polyvinyl chloride plastic liberate hydrogen chloride when incinerated. This emission of hydrogen chloride can be reduced in several ways. Firstly the incineration can be carried out in an incinerator that has an emission control system such as a scrubber or secondly (and probably preferable) the amount of PVC in the waste can be reduced by the hospital administration eliminating where possible the use of PVC containing products. The Manitoba Health Services Commission is endorsing the latter option while taking a wait and see option on Ontario Incinerator Regulations.

The setting up of regulations and guidelines cannot address all materials and situations. However, cooperative legislation between government agencies and hospital administrators can result in a safe and workable solution to hospital waste handling and disposal.

Summary

The issue of handling waste material within a health care facility can be considered aesthetically repulsive to the general public. This material is best processed internally by personnel trained in the handling and disposal.

Proper handling and disposal is regulated by various acts and regulations and enforced by the Manitoba Department of Environment and Workplace Safety and Health. The hospitals within the Province have adopted in principle the CSA Standard "Handling of Waste Materials Within Health Care Facilities". The ultimate result is the proper handling of waste from its source of generation to the final disposal.

There are many new questions which have surfaced as a result of the increased scrutiny of hospital waste. Incinerator performance, hazardous waste inventories and waste quantity generation are presently undergoing investigation. Once the data are compiled on these categories, a new strategy may be implemented for the Handling of Biomedical Waste.

ROLE OF MACRO-PORES IN CLAY LINERS: A CROSS-CONTINENTAL EXPERIENCE

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ABSTRACT

The importance of macro-pores, as formed by desiccation cracking, to moisture transport through the compacted clay layers of a landfill cover liner is presented. Earlier theories have assumed that micro-pore processes control the transport, while modeling the clay liner as a homogeneous material with a monolithic structure. The existence and importance of cracks is documented using previously collected laboratory and field data from the U.S. and European countries. Although micro-pore flow can be modelled confidently using Darcy's Law, its application to macro-pore flow has not been documented. The variety of modes and mechanisms of flow that are operative in flow through cracked clay liners is discussed, and analogies are made to familiar concepts in open channel flow theory. The discussion provides the conceptual framework for the development of a numerical model to simulate both the micro-and macro-pore phenomena.

INTRODUCTION

One of the primary functions of a landfill cover liner is to minimize the moisture inputs to the deposited waste. Any moisture added to the waste increases the probability of contaminant leakage through the base of the landfill.

The cover liner consists of a layer of the compacted clay alone or its combination with a synthetic membrane. The synthetic membrane acts as a "back up" to the clay. A sand layer is included to facilitate lateral flow of the leakage towards collection pipes which route the moisture off-site.

The synthetic membrane of the cover liner can effectively perform its function only as long as it remains intact. Haxo (1981) has reported on the puncturing of synthetic membranes due to the compaction efforts of construction equipment on the overlying clay layers. Gray (1984) has also reported on the increased leakage through these membranes due to seams and pin holes. Infiltration may also pass through faulty seals around the manholes, vent pipes, and other items that pass through the cover liner. These findings considerably reduce the reliability of the synthetic membranes as a barrier for moisture movement. Hence, the ultimate responsibility of reducing the generation and the leakage of the leachate from a landfill shifts to the clay cover liner.

MATHEMATICAL MODELLING OF FLOW THROUGH THE COVER LINER

Mathematical modelling of the leakage through the clay cover liner has been attempted by Remson et al. (1968), Fenn et al. (1975), Perrier and Gibson (1980), Skaggs (1980), Miller (1984) and Schroeder (1984a and b). The first three of these researchers have used the water balance method, without considering the mechanism of the fluid flow through the porous media, to estimate the leakage. This approach has been found to result in gross underestimates of the field conditions (Gee, 1981; Gibson and Malone, 1982). Skaggs (1980) improved over the earlier attempts by incorporating Darcy's equation in his model to compute the rate of moisture movement through the saturated porous media. Both Miller (1984) and Schroeder (1984a and b) used a quasi-two-dimensional, deterministic approach to model flow through the cover liner. Schroeder's model assumes the clay liner to be saturated, while Miller's model covers the full range of saturation. However, Schroeder models the surface hydrology, while Miller's model requires the user to provide the surface inputs. In Miller's model it is assumed that the surface inputs (i.e., the flux boundary condition) have been solved for apriori, using a model of the surface hydrology.

All of the above-mentioned researchers have assumed the clay liner to be a homogeneous mass of clay with uniform hydraulic properties. The hydraulic conductivity values used in the models are determined in the laboratory and, hence, do not represent the actual field values. In a recent study, Daniel (1984) found that fluid moves much faster through the clay liners than predicted with the laboratory determined values of hydraulic conductivity. He discovered that the actual hydraulic conductivities of the clay liners, back calculated from the field leakage rates, were from 5 to 10,000 times larger than those obtained from the laboratory tests on either undisturbed or recompacted samples of the clay liners. Researchers attribute this increased hydraulic conductivity in the field to the presence of the macro-pores in the clay mass (Daniel, 1984; Boynton and Daniel, 1985).

A macro-pore can be defined, typically, as a void space in the soil mass which is larger than that formed by the individual soil particles placed side by side in a soil matrix (Figure 1). Cracks, fissures, root holes, and wormholes are some examples of the macro-pores generally found in a soil mass.

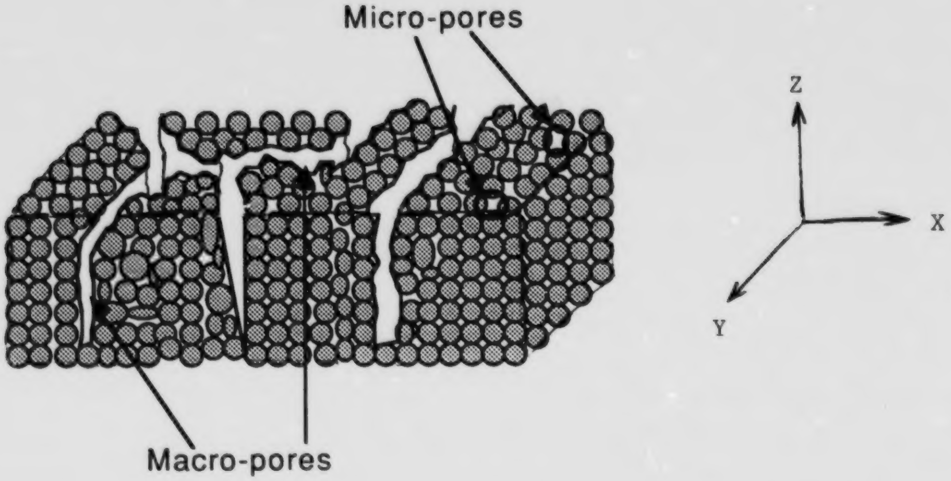


Figure 1. Macro-pores and micro-pores in a soil layer.

OBSERVATIONS OF FLOW THROUGH MACRO-PORES

Rapid movement of surface-applied water through the macro-pores may be a novel speculation for investigators estimating leakage through landfill liners. However, it is a long established fact for agricultural and petroleum engineers. According to Beven and Germann (1982), the concept of rapid movement of water through macro-pores was first described by Schumacher (1864) who wrote: "...the permeability of a soil during infiltration is mainly controlled by big pores, in which the water is not held under the capillary forces." Later, Lawes et al. (1882), Horton (1942) and Hursh (1944) also reported on the rapid movement of surface applied water through macro-pores. Hursh (1944) has clearly stated that: "...in considering flow through upper soil horizons, the formulas of soil mechanics do not generally apply. Here porosity is not a factor of the individual soil particle size but rather of structure determined by soil aggregates which form a three-dimensional lattice pattern. This structure is permeated throughout by biological channels which in themselves also function as hydraulic pathways. A single dead-root channel, wormhole or insect burrow may govern both the draining of water and escape of air through a considerable block of soil."

Recently, Edwards et al. (1979) have reported that Gardner (1962) also showed that the holes and the cracks, that are open at the surface, can definitely move significant volumes of the free surface water much deeper and faster than can be calculated by the Darcy-type solutions alone. The tracer studies of Ritchie et al. (1972), Blake et al. (1973), and Quisenberry and Phillips (1976) also revealed that the surface-applied water flows through the interconnected macro-pores. Miller (1986) has also mentioned that if flow through the cracks in a landfill liner is significant, her numerical model is expected to under predict the leakage through the clay liners.

QUANTIFYING THE INFLUENCE OF MACRO-PORES

The first reported observation of flow through macro-pores (Shumacher, 1864) is contemporary to the initial discussion of flow through the micro-pores in a porous medium (Darcy, 1856). Although the importance of micro-pores in fluid flow through porous media is now well understood and quantified through Darcy's equation, not much has been achieved in understanding and quantifying the flow through the macro-pores. Some efforts made by various researchers to quantify the influence of the macro-pores on infiltration through a soil mass are presented subsequently. European contributions to understanding the mechanisms of cracking in clay liners are also included.

Davidson (1984) has presented a model to trace the motion of a wetting front travelling into a soil containing regularly spaced, water filled cracks of negligible width. At the beginning of the wetting process, two sharp fronts, separating the wetted region from the unwetted one and advancing in intersecting directions are presumed to originate and grow away from the top surface and the crack. Initially, the former advances as a one-dimensional flow and the latter exhibits a mushrooming effect with the lateral advance near the tip of the crack being greater than at the base.

Since the macro-pores considered in the Davidson's model are isolated, of negligibly small aperture and closed bottom, the question of the drainage through them is meaningless. Hence, Davidson's findings are applicable to the clay liner problem only for understanding the movement of the wetting front in individual soil blocks surrounded by the cracks.

An attempt to mathematically model the influence of the macro-pores of finite aperture on the soil-water movement was made by Edwards et al. (1979). Using a level field with a large number of regularly spaced, round, vertical wormholes, they considered a single hole and a small cylindrical column of the soil around it. Their model simulates the flow of water, falling on the top surface of this vertical soil column, by using Richard's equation with many assumptions: the soil properties and the initial water content are uniform with the depth, the soil remains unsaturated throughout the rainfall, and the soil column receives heavy precipitation of constant intensity.

This approach was improved by Beven and Clarke (1986). In addition to the infiltration from the sides of the circular macro-pore, vertical infiltration from its bottom is also considered. They modeled the infiltration into a soil profile due to the stochastic variance in spatial occurrence of the macro-pores. The results obtained by considering a single circular channel are generalized by considering the statistical population of channels with a given probability distribution of radii and depth. The vertical axes of the cylindrical channels are assumed to intersect the horizontal soil surface at the points having Poisson distribution. The assumptions made by Beven and Clarke for the model formulation restrict the model applications to a soil containing vertical, isolated, and circular conduits. In addition, since the model considers the infiltration into the soil matrix from the macro-pores and not the flow through them, its direct application to the liner problem is not possible.

Bouma and Dekker (1978) had observed that the depth and the patterns of the vertical penetration of water along the cracks in the dry, heavy clay soils were a function of the intensity and the duration of the rainfall event. They sprayed different quantities of dilute Methylene-blue solution, using different intensities, over 37 rectangular plots of 100 cm by 50 cm. On excavating these plots to a depth of 1 m, they observed that, in a crack, instead of flowing along whole of the crack length, the solution was visible only along a few 5 to 7 mm wide bands. The area of these bands, made visible by the blue stains, was added together to get the total area, S, through which the transfer of water from cracks to the surrounding soil matrix took place

Hoogmoed and Bouma (1980) utilized the findings of Bouma and Dekker (1978) to estimate the transfer of surface-applied water to a soil profile containing surface-connected cracks. In their model, they incorporated the models of Van Keulen and Van Beek (1971), to estimate the vertical flow through soil layers, and Van der Ploeg and Benecke (1974), to estimate the horizontal absorption of water by an initially dry soil. They used the technique of Bouma and Dekker (1978), described above, to determine the wetted surface area, S, of water carrying cracks through which the absorption into surrounding soil matrix takes place. Their model assumes that:

1. the soil is initially dry,
2. the ponding of the water starts when the rainfall rate exceeds the rate of infiltration,
3. the water starts flowing in the cracks when the depth of ponding reaches a preset, threshold value, of 0.2 cm based on visual observations, Hoogmoed and Bouma (1980)
4. all of the excess water flows into the cracks, and
5. the drainage from the soil starts when the flow rate into the cracks exceeds the total horizontal absorption of all layers.

The model simulates the movement of the surface applied rain-water through a 20 cm thick layer of soil containing cracks. For calculation purposes, this soil layer is divided, from bottom to top, into 11 layers: 9 of 2 cm thickness and one each of 1.5 cm and 0.5 cm. Water reaching the bottom of the soil layer is considered as the drainage water.

The results of this simulation show that depending on the initial moisture content of the soil and the rainfall intensity, the rate of drainage can be up to 97% of the rainfall intensity. High drainage rates like this, although in agreement with the corresponding drainage rate (98%) measured by Bouma et al. (1978), are not expected from a landfill liner because their assumption of all of the excess water flowing into the cracks is not valid there. Field observations by the authors indicate that, mainly because of the liner geometry, a part of the excess water always flows off the landfill surface.

Another outcome of this model, the one we may find very useful in modelling the leakage through the cracked liners, is that the vertical infiltration is more important than the horizontal absorption for heavy clay soils. With the passage of time, as the wetting front travelling down through a soil mass reaches a particular depth, the horizontal absorption at this depth reduces. Hoogmoed and Bouma (1980) expect that for the soils with a texture coarser than that of the clay soils considered in their model, the horizontal absorption may be quite significant. This correlation of the soil texture with the horizontal absorption can form the basis for the assumption that the horizontal absorption in the liner clays, having a very fine texture and low permeability, will be negligible. This assumption will help reduce the complexity of the mathematical model for estimating the leakage through the cracked liners without adversely affecting the leakage estimates.

The model of Hoogmoed and Bouma (1980) has limited utility for estimating leakage through cracked liners. Information about the depth and the amount of vertical infiltration into the surface peds can be obtained from it, but an accurate estimate of flow into the cracks is not possible.

Other authors, such as Gray (1984), have suggested the concept of "equivalent hydraulic conductivity" to account for the complex interaction of micro- and macro-pore flow in a cracked liner. Such an equivalent value would require a laboratory determination whereby the total flow exiting the cracked system would be measured. The equivalent hydraulic conductivity resulting from such a determination would be the coefficient in Darcy's equation resulting in an equality between flow and hydraulic gradient, and would, in some sense, reflect an "averaging" of the two flow mechanisms. The problem is that the equivalent hydraulic conductivity would apply only to those specific laboratory conditions for which it has been calibrated. For different rainfall intensities, micro-pore structures, clay types and crack geometries, the relative importance of macro-pore vs micro-pore flow will change. Because the concept of equivalent hydraulic conductivity does not incorporate the actual physical mechanisms underlying the flow processes, it is not generally applicable.

Bronswijk (1988) investigated the agricultural implications of moisture transport in soil macro-pores. Bronswijk uses a water balance approach to model the vertical movement of water through a clay soil, from the surface to the underlying groundwater. The primary contribution of his work is the introduction of the concept of a "shrinkage characteristic". He demonstrates that this characteristic curve may be used to relate moisture fluctuations in the soil to volume changes, which comprise both subsidence and cracking. Using assumptions of crack depth, the aggregated surface area of cracks is determined. The rainfall is then dynamically partitioned between the cracks and soil matrix. Bronswijk neglects any horizontal absorption as the water flows down the cracks, assuming it all accumulates at the bottom of the crack. Also, this approach assumes negligible resistance to flow through the cracks and that flow into the cracks is limited only by the surface area of the cracks. Surface runoff is neglected, as Bronswijk assumes a horizontal soil surface. However, landfill cover designs require a surface slope to promote runoff.

As revealed by this literature review, existing models of flow through macro-pores are not sufficiently developed and suitable for the simulation of the leakage through clay liners. Either their scope is limited to estimating the infiltration into the soil matrix, from the macro-pores, or their methodologies limit their utility to the liner problem. Therefore, the mathematical modelling of the leakage through the clay liners demands a fresh and innovative investigation of flow through macro-pores specific to the liner environment. Such an investigation will also require an understanding of the mechanisms of desiccation cracking, leading to a descriptive model for the time progression of cracking as a function of site conditions. European investigators have taken the lead in this area.

Goettner and Braun (1988) provide some clues as to the soil suctions which lead to cracking of the clay. Their primary subject of study is the type of above-ground waste heaps often constructed in Europe. At these sites, cracking of the bottom liner is a problem. The authors contend that at soil suctions less than 2.5 Pf crack formation will not occur. They relate this suction to the equilibrium moisture content that will exist in the liner placed a specific distance above the ground water table. At a separation distance of 3 m, the equilibrium moisture content will lead to a soil suction of 2.5 Pf. Therefore, this is recommended as the maximum separation distance between liner and groundwater. The authors develop a relationship between crack potential and soil activity, clay content, and grain size distributions.

Holzloehner (1987) follows up on these ideas, calculating the soil suctions expected in clay liners under several different hypothetical designs. Holzloehner recommends that landfill designers determine the equilibrium soil suction in the liners corresponding to the site conditions, and evaluate how this corresponds to the cracking suction of that soil. The design may have to be modified to incorporate some moisture-holding features if this calculation shows the equilibrium suction to exceed the cracking value. Holzloehner also discusses the importance of temperature gradients on leakage flow through liners.

Bronswijk (1986) examines the effect of evaporation and transpiration on the cracking of a heavy Dutch clay soil through laboratory experiments on small and large core samples. Volume loss upon moisture removal is broken down into subsidence and cracking. He concludes that the greatest and most important part of the shrinkage process that occurs upon water removal is normal. From saturation down to a moisture content of 0.32, every volume of water that is extracted from the soil aggregates results in an equal amount of volume loss of the aggregates. Initially, evaporation takes place with no resulting surface subsidence. This can be attributed to structural shrinkage; water evaporates out of large macro-pores and cracks without extraction out of the clods. Thereafter, subsidence starts while total crack volume increases from 960 cm^3 (3.2%) to 1717 cm^3 (5.8%). After about 20 days, a steady state is reached, where the evaporation rate equals the flux of water through the bottom. Subsidence then become negligible. Plant roots are not able to remove moisture from the cracks because the suctions exceed the wilting points of the plants. Therefore, roots will cover crack walls and aggregate surfaces.

CONCEPTUAL MODEL OF THE MACRO-PORE HYDRAULICS

A clay liner consists of one or more layers of clay characterized by high plasticity index and compacted to yield very low hydraulic conductivity. Multi-layer liners are constructed by the sequential compaction of the individual clay layers on top of one another. In the case of landfill cover liners, the topmost layer of the compacted clay is overlain by organic soil, also known as the topsoil, to support the vegetative cover on the landfill. The mineralogical composition, the degree of compaction, and the physical and biological environment of the liner clay and the topsoil differ considerably. As a result, the macro-pores in these two components of the cover liner also differ in their origin and type. The mechanisms of flow through them are also different and a clear understanding of these different flow mechanisms is vital for the mathematical modelling of the leakage through the clay liners.

The topsoil layer of a cover liner is densely populated by the plant roots and provides habitat to the worms and the burrowing animals associated with the vegetation. This situation leads to the formation of the macro-pores that can be approximated by circular conduits. A significant fraction of the runoff generated on the landfill surface may be directly conducted to the topmost layer of the compacted clay by a network of such interconnected conduits. In due course of time, a part of this infiltrated water may also reach the top of the compacted clay layer by seeping out from the soil matrix into the interconnected channel network. Thus, the total amount of leakage through the topsoil layer is expected to be much more than estimated by the existing models that do not consider the flow through the macro-pores. This unaccounted increase in leakage through the topsoil layer also increases the importance of the underlying compacted clay layers for impeding the further movement of the moisture. Therefore, a careful investigation of the macro-pores in the compacted clay layers, and the mechanisms of flow through them, becomes even more important.

The compacted clay portion of a landfill liner consists of one or more layers of clay compacted sequentially on top of one another. The density and the moisture content of each of these layers is kept close to their respective optimum values to obtain low hydraulic conductivity. The compaction of a layer takes several days or longer and may not be immediately followed by the compaction of the next layer. During all this time, the compacted clay layer is exposed to the atmosphere. Consequently, it experiences the drying associated with wind exposure and temperature effects and subsequently develops desiccation cracks (Photo 1).

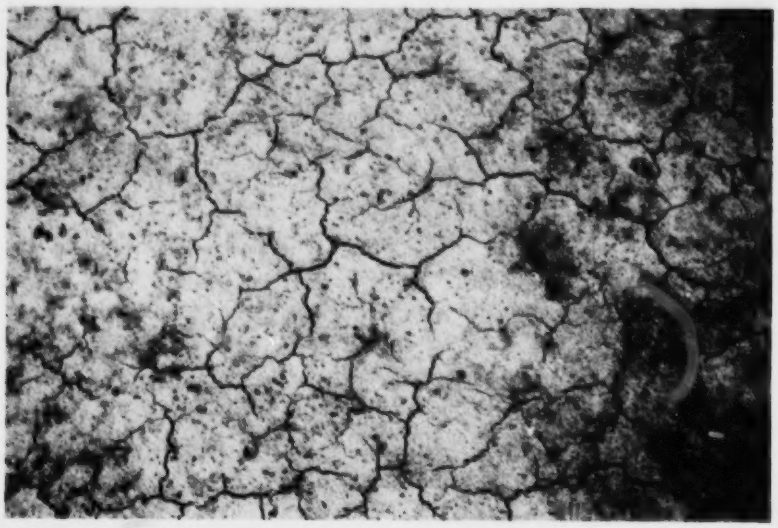


Photo 1. Desiccation cracks on layer of clay liner due to wind and temperature.

During their field studies (Miller, et al., 1987), the authors have found that the desiccation cracks - uniformly distributed over the entire compacted clay layer - can exceed one centimeter in width (Photo 2). These cracks form vertical channels which may penetrate the entire depth of a compacted layer. Depending on the duration of the atmospheric exposure and the local climate, the development of desiccation cracks can finally break the initially homogeneous compacted clay layer into much smaller individual clay peds. These peds are completely isolated from their surroundings by means of the cracks and can virtually be removed from the clay layer with little effort and negligible interaction with the surrounding soil. In such a physical state, the clay layer contains vertical channels distributed throughout. Such channels can significantly reduce the effective thickness of the compacted clay liner. In addition, they can quickly conduct a significant portion of the surface runoff directly to the bottom of the clay liner.

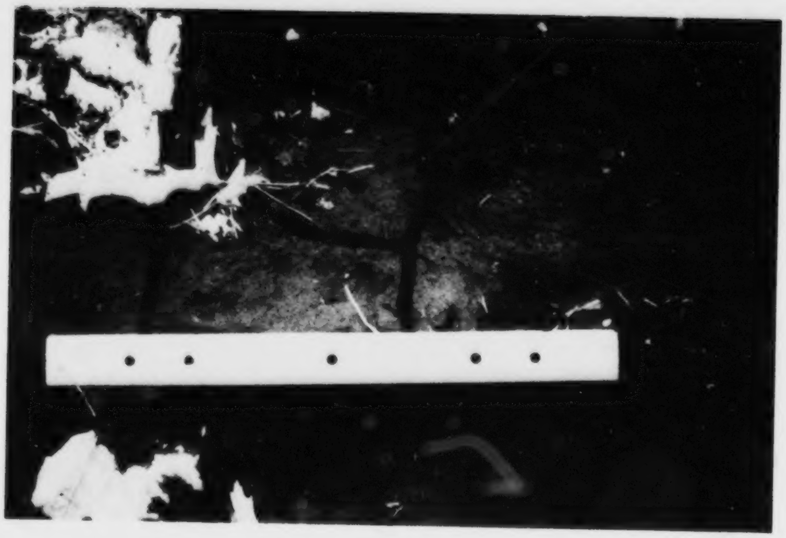


Photo 2. Desiccation cracks uniformly distributed over the compacted clay layer. Cracks can exceed one centimeter in width.

Shrinkage of the compacted clay during the desiccation process may actually reduce the hydraulic conductivity of the clay forming the individual peds. However, the channels formed around the peds, by the desiccation cracks, increase the hydraulic conductivity of the compacted clay layer as a whole. As a result, during a rainfall event, the infiltration through the matrix of the individual peds may be desirably low while the volume and the rate of leakage through the whole layer may be unacceptable. In a situation like this, the conventional laboratory tests, on small samples from individual peds, may indicate compliance with the regulatory requirements for hydraulic conductivity while, in fact, that is not the case.

Some investigators have suggested that the problem of clay cracks is limited in liners because of the multi-layer approach. They reason that the multi-layers will buffer lower clay from environmental effects and the propagation of cracks. However, when a cracked clay layer is overlaid by a layer of the loose clay to construct the next compacted layer, not all of its cracks are completely filled up. In addition, the depth of the clay layer is greater than the length of the sheepsfoot in the rollers used for the compaction. Therefore, the channels in the underlying old clay layer stand a good chance of remaining intact and unsealed. They are merely filled up by the loose clay and remain highly permeable as compared to the clay matrix surrounding them. In due course of time, the new layer also develops desiccation cracks and the associated channel network. Now, the flow paths in the combination of the two layers appear similar to those in Figure 2.

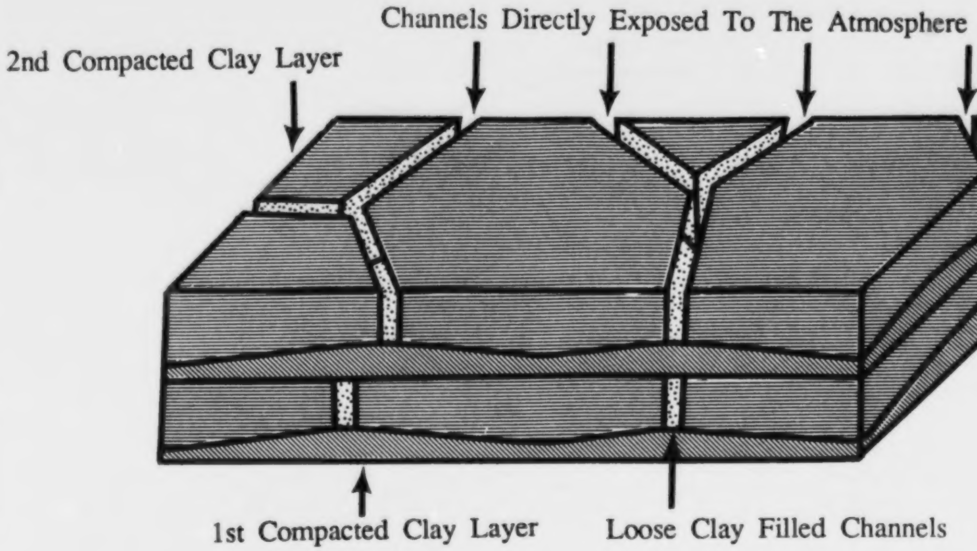

Channels Directly Exposed To The Atmosphere
2nd Compacted Clay Layer
1st Compacted Clay Layer
Loose Clay Filled Channels

Figure 2. Flow in loose clay filled channels of a double layered clay liner.

During a rainfall event, the channels in the top layer deliver a portion of the surface runoff to the underlying, loose clay filled, channels. When the rainfall ceases, some of the runoff is stored in channels in the top layer and finally leaks through the underlying loose clay filled channels. The construction of each new layer adds an additional layer of loose clay filled channels to the existing flow paths. Each of such successive layers increases the delay in the onset of leakage due to a rainfall event. Successive reduction in the volume of leakage is also expected, and is brought to a minimum by the deposition of the topsoil layer. At this stage, the macro-pores constituting the flow paths responsible for leakage through the top-cover clay liner would look somewhat similar to those in Figure 3.

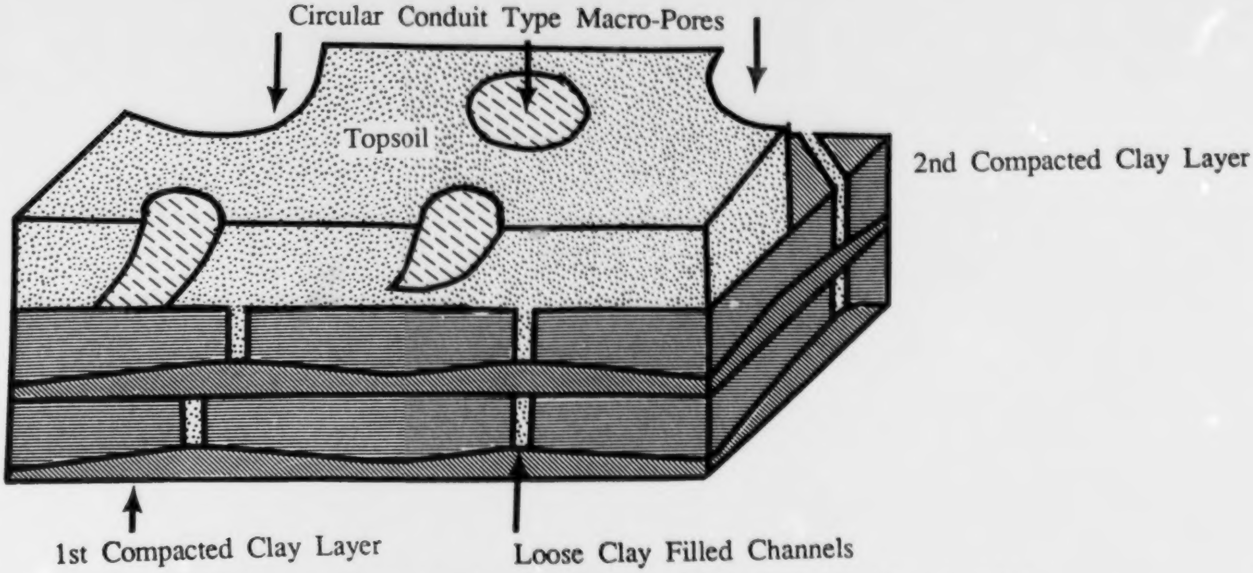


Figure 3. Flow channels in a double clay layer liner with topsoil.

MODES AND MECHANISMS OF FLOW THROUGH LINER MACRO-PORES

Field investigations of the physical structure of the landfill cover liner, and the macro-pores in it, clearly indicate the existence of three distinctly different modes of flow through a liner. They are encountered during the different stages of the liner construction and, during each mode, a particular combination of six different flow mechanisms is responsible for the leakage through the compacted clay liner. Therefore, a clear understanding of all three modes and the six mechanisms is indispensable to the development of a mathematical model which accurately simulates the physical problem. All three modes and their associated flow mechanisms are briefly described below.

Flow through channels in the surface-exposed macro-pores of clay cracks comprises one mode of flow. It commences following construction of the lowest layer of compacted clay and persists at the top of each subsequent clay layer until the deposition of the topsoil layer. Therefore, it is operable only during the cover construction.

For a short initial period during a rainfall, the nature of flow in the channels is speculated as similar to that of free-falling water over a weir. The duration of this period of flow is width-dependent and varies with the intensity and duration of a particular rainfall event. Since the rate of flow in interconnected channels is limited by the outflow at the intersections, a channel starts filling up when the rate of inflow into it exceeds the rate of outflow at its intersections. The narrower channels are filled up earlier than the wider ones and the free-falling flow is discontinued as soon as they are full. Consequently, the free-falling type of flow is most important in the wider channels.

If the velocity of the surface runoff provides sufficient kinetic energy, the second mechanism commences. With this flow mechanism, the volume of the runoff passing over a crack is divided into two parts. One part enters the crack as weir flow described previously, while the other part passes over the crack to continue as overland flow down the slope (Fig. 4). The value of the critical velocity at which the flow partitioning takes place varies with the crack width. The proportion of the runoff volume comprising each part depends on the flow velocity and the crack width.

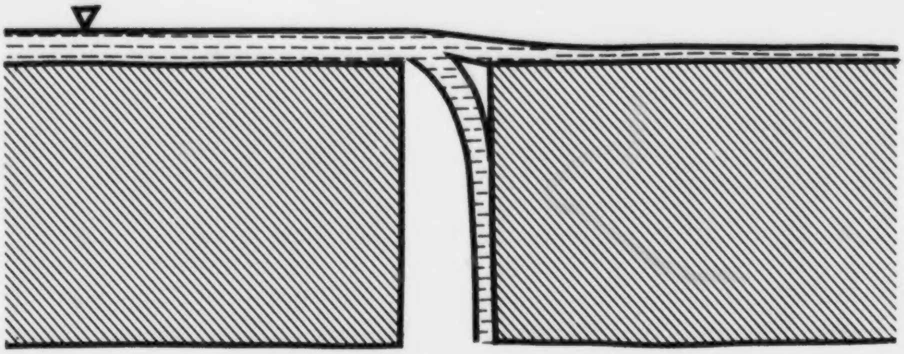
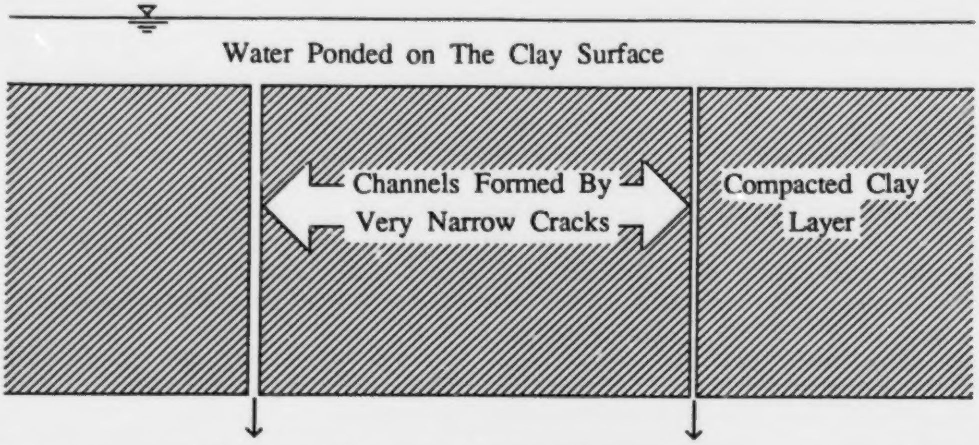


Figure 4. Flow partitioning over a wide channel in a clay liner.

After the macro-pores have filled with water (expected to be a very short time after the initiation of rainfall), the nature of flow in the associated channels is similar to that in closed rectangular conduits with permeable surfaces, flowing full. This flow mechanism requires sufficient ponding of the water, on the upper surface of the compacted clay layer exposed to the atmosphere, to provide, at least, a threshold hydraulic head (Fig. 5). The flow into the water filled openings is



Water Ponded on The Clay Surface
Channels Formed By Very Narrow Cracks
Compacted Clay Layer

Figure 5. Ponding on the clay liner surface causing flow through narrow cracks in the clay.

controlled primarily by the Darcy type flow into the underlying loose clay filled channels and horizontal absorption into the surrounding peds.

A second mode of flow through the macro-pores in a clay layer is operable in the loose clay-filled channels and is initiated due to the movement of a wetting front through the overlying clay layers. The channels in the overlying layers can be either loose clay filled type, those directly exposed to the atmosphere, or the circular conduit type macro-pores in the topsoil. Therefore, this second mode of flow is applicable only after the compaction of the second lowest layer, in a multi-layer liner, or after the deposition of the topsoil layer. The flow mechanism is similar to that in the Darcy flow through the soil micro-pores. Factors controlling the flow rate include: hydraulic head in the overlying clay layers, the average minimum width of the channels, and the hydraulic conductivity of the clay filler. It is assumed that the wetting front is advancing from above, and there is no restriction to flow at the bottom of the channel.

The third mode of flow exists only in the topsoil layer, where the macro-pores are primarily due to worm holes and root holes. The circular conduit type macro-pores do not develop until growth of the cover vegetation. Until then, infiltration is due to Darcy flow through the soil matrix. As time passes, the penetration of the plant roots and the activities of worms and burrowing animals provide the circular conduit type macro-pores in the topsoil. The flow mechanisms are identical to those described for the first mode, in channels directly exposed to the atmosphere. A portion of the water flowing in the circular conduit type macro-pores infiltrates into the surrounding soil matrix. However, after the rainfall, the water from the soil matrix infiltrates into the macro-pores resulting in an increase in the volume and the duration of the leakage from the topsoil layer.

CONCLUSIONS AND RECOMMENDATIONS

The importance of clay liners to the containment of landfill waste has been documented. Assessment of the containment efficiency of a proposed landfill requires the determination of the volume of moisture which is expected to leak into the waste through the cover clay liner. Several models are currently available to simulate the performance of the landfill cover liner. However, these have been shown to underestimate the actual leakage volumes. The existence of macro-pores, especially attributed to desiccation cracking, is hypothesized as the cause of this discrepancy.

Although there have been previous attempts to model flow through soil macro-pores, especially in agricultural engineering, the simplifications employed have rendered the models insufficient for the clay liner problem. Most importantly, previous investigators have bypassed a theoretically robust hydraulics theory encompassing macro-pore flow. Instead, previous models have been phenomenological in nature, and are primarily site-specific.

The conceptual model of flow through cover liners that has been presented acknowledges the existence of macro-pores. Flow through the clay matrix would be modeled using Darcy's Law, while the macro-pore flow component would be modeled using the equations governing analogous processes in open channel and closed conduit hydraulics. These equations are well developed and verified in other applications. Future investigations will provide the complete mathematical model of flow through clay liners incorporating the macro-pore concepts. Collection of field data for verification of the model is underway.

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"TRANSFER STATIONS - SOME FORWARD THINKING"

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Paper unavailable at time of printing

MOBILE DESTRUCTION SYSTEMS
(An Overview)

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Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of solid hazardous wastes. These materials, if improperly dealt with can pose a threat to both health and to the environment. Abandoned waste sites and accidental spills of toxic and hazardous substances ultimately require proper disposal. This paper reviews some of the mobile technologies available to destroy hazardous wastes.

This review is by no means exhaustive. It attempts to provide a summary of the more established commercial technologies and also some of the more promising ones.

These units could be used in situations involving hazardous chemical spills and detoxification of abandoned sites where transportation of large quantities of hazardous materials to a fixed site may be impractical or expensive. Also, transportation across political boundaries is becoming more difficult. Destruction of toxic materials at specific locations, where those materials are situated, seems to be a rational solution to a very difficult problem. A truly mobile or transportable system may avert the potential of permanency and relieve public concern about the possibility of becoming a major toxic waste disposal center.

This review considers the following criteria for mobile units:

*it must be transportable.
* it must be capable of handling solids, liquids and sludges of varying concentrations.
* the process should be available for application and constructed or available for construction upon receipt of the order.

Incineration

Incineration is not a new technology. It has been commonly used for treating wastes for many years throughout North America and Europe. The major benefit of incineration is that it virtually destroys most of the waste rather than either disposing of or storing it. Incineration can be used for a variety of specific wastes and is reasonably competitive in costs. Despite the many types of incineration technologies which appear to be available today, few have stood the test of time. The two technologies that have predominated are the rotary kiln and the liquid injection systems. One of the chief variables in the operation of different types of incineration systems is the amount of air used. Most incinerators operate with air in excess of stoichiometric requirements. Some incinerators operate in a starved air mode in the kiln or primary chamber with the excess air being supplied in the afterburner of secondary combustor.

The rotary kiln, the most popular method of treating solids or semi-solids, is a horizontal rotating cylinder, lined with refractory material into which waste is introduced by either a ram, gravity feed or, as in the case of sludges, a pumped feed or sludge lance. In many cases the rotary kiln must be supplied with additional fuel to maintain combustion. Large diameter solid material can be fed into the kiln while liquids are often injected simultaneously into the kiln or the secondary combustor. Operating temperatures are typically 800 to 1000°C in the kiln or primary combustion chamber and 1000 to 1300°C in the afterburner or secondary destructor.

A number of companies are entering the hazardous waste destruction market. Most of these new entrants into the field have demonstration units that can handle wastes on a pilot plant or prototype basis. There is reason to believe that there is great promise for some of these units.

Alternative Technologies

Alternative technologies are defined as technologies, both existing and new that offer practical alternatives to conventional incineration of hazardous wastes. Each alternative technology is described and discussed in terms of the waste the system is accepting, throughput, capacity of the process, operational costs and anticipated environmental impact.

Currently there are many new processes in various stages of development for treating and destroying hazardous waste (Table 1). The costs for the emerging processes; High Temperature Electric Reactor and Molten Salt, appear at least comparable to conventional incineration. The costs for Supercritical Water, and the Plasma Arc will probably exceed those of incineration. Each of the emerging technologies may offer other advantages over conventional incineration and for specific waste streams may justify the higher costs. Many of the emerging technologies are still being evaluated, or are experimental in nature. It is not expected that they will have a large impact on the hazardous wastes being treated by conventional methods.

Mobility

Although many units are transportable (ie they are skid mounted), few are truly mobile. Many manufacturers have indicated that they would design and supply a mobile unit to suit a particular request. The design and fabrication of these units however, requires a considerable amount of experience along with unique and highly specialized approaches. Comparisons are presented in Table 2.

Feed Rate

Waste throughput varies with a number of factors. High moisture content of the feed limits the throughput. High excess air requirements may also reduce the rates significantly. The physical shape and size and properties of the material

Table 1   ALTERNATIVE TECHNOLOGIES

	Process Name	Description	Waste Streams
WET OXIDATION	Zimpro Wet Air Oxidation	Uses elevated temperature and pressure to oxidize organics in water	Aqueous streams with less than 5% organics
	IT Catalyzed Wet Oxidation	Uses selected catalysts and elevated temperature and pressure to oxidize organics	Aqueous waste stream with suspended organics
	MODAR Supercritical Fluid Oxidation	Uses high temperatures and very high pressure to oxidize organic contaminants in water	Aqueous slurries or organic solutions
	Methods Engineering High Temperature Wet Oxidation	Uses long vertical underground tubular reactor to oxidize suspended organics in water	Liquids or sludges
CHEMICAL TRANSFORMATION	Battelle Northwest Aqueous Phase Alkaline Destruction of Halogenated Organics	Converts halogenated organics into an oil using mild alkali under pressure	Halogenated liquids and granular solids
	GARD Catalytic Dehalogenation of Hazardous Wastes	Dehalogenizes compounds by replacing halogen atom with hydrogen atom	Liquids with high concentration of halogen compounds
MOLTEN GLASS	Battelle Northwest Joule Heated Glass Melter	Applies electric current directly to waste material for combustion and for creation of a glass matrix	Soils and other granular mineral matter
	Penberthy Electromelt Pyro Converter	Uses a bed of molten glass to oxidize organics and to capture ash and inorganics	Any liquid or solid waste stream
FLUIDIZED BED INCINERATION	Battelle Columbus Multisolid Fluidized Bed	Uses a moving bed of heated inert material to incinerate wastes	Granular solids, sludges, slurries, liquid and gases
	GA Technologies Circulating Bed Waste Incineration	Uses a circulating mass of heated inert material to incinerate waste materials	Solids, sludges, and liquids
	Waste-Tech Services Low Temperature Fluid Bed	Uses granular combustion catalyst and limestone in a fluid bed	Liquids, sludges, slurries, or soils

Table 1 ALTERNATIVE TECHNOLOGIES cont'd

	Process Name	Description	Waste Streams
PYROLYSIS	Midland Ross Pyrolytic Decomposition	Heats waste materials in the absence of oxygen to drive off volatiles for incineration or recovery	Viscous liquids, sludges, and high ash materials
	Russell and Axon High Temperature Pyrolysis with Oxygen	Uses oxygen induced high temperature to pyrolyze water	Solids and liquids
MOLTEN SALT	Rockwell International Molten Salt Destruction	Uses a bed of molten sodium carbonate to destroy wastes and scrub acid gases	Low ash, low water content, solid or liquid wastes
ADVANCED INCINERATORS	Industronics Consertherm Rotary Kiln	A modular controlled air incinerator	Liquids, sludges, or solids
	PEDCo Technology Fast Rotary Reactor	A rapidly rotating cylinder utilizing dryer technology for waste incineration	Solids or sludges
	IGT "Cyclin" Cyclone Incinerator	A cylindrical shaped combustion chamber provides for intensive mixing of fuel and air	Gases or atomized liquids
ELECTRIC REACTOR	Thagard High Temperature Fluid Wall Reactor	Uses electrically induced radiant heat to pyrolyze organic contaminants	Granular solids
	Huber Advanced Electric Reactor	Uses electrical heat to pyrolyze organic materials at extremely high temperatures	Finely ground solids
PLASMA SYSTEMS	Pyrolysis Systems Pyroplasma	Uses plasma arc device to create extremely high temperatures for waste destruction	Highly toxic liquids
	Applied Energetics Plasma Temperature Incinerator	Burns waste in a pressurized stream of preheated oxygen	Liquids and fluidized solid waste

Source: Innovative Thermal Hazardous Waste Treatment Processes, U.S. EPA being fed into the unit is also a factor.

The incinerator flame volume limits the feed rate of high BTU content feedstocks. Another factor can be the solids, ash and inerts resident in the destructor. This is especially true with rotary kiln types of incinerators.

Such solids are subject to a resident volume limit of the kiln as the solids must be retained in the kiln until the toxic substances are either destroyed or volatilized. The most important factor that limits feed rate are moisture, excess air, BTU content, kiln residence time (solids) and the secondary chamber dwell time.

Staff Requirements

Staff requirements vary somewhat especially with respect to maintenance, personnel, and the destruction process being used. Initially, and during commissioning, the following operating personnel would be required:

- **Operators** - Four per shift for a total of 16
- **Maintenance** - One Mechanic-Electrician
- **Staff** - One Supervisor, one Chemist, one Process Engineer and one Health and Safety Supervisor.

It may be practical to include additional maintenance personnel, depending upon start-up and operating circumstances.

Waste Feed Systems

Most suppliers indicate that the feed systems could be tailored to meet specific requirements. Except for unique circumstances, most systems normally comprise of the following:

- solid waste shredder
- hydraulic ram feeder
- sludge and liquid feeders

Due to the solid size restriction for a number on the destructors, a further size reduction may be required.

Utilities

For incinerators, either fuel oil or gas supplied from external sources is used as auxiliary fuel and in many instances the utilization of liquid waste as a supplement to auxiliary fuel will substantially reduce treatment costs. The facility must have access to either of these fuel sources (fuel oil, natural gas, butane or propane)

Normal electrical power requirements are 480v three phase at approximately 200 KW. This is sufficient to run the various pumps, motors and supply electrical requirements for the monitoring facilities. For some alternative technologies that use electricity as the sole source of power, the Plasma Arc and the Advanced Electric Reactor will exceed this figure by a considerable margin.

Compressed air may be used for liquid fuel atomization. This should normally be incorporated with the mobile system. If, however, external sources are required, approximately 150 scfm will be required.

If a wet scrubbing system is selected, process make-up water will be required. Typical rates ranges as high as 20 to 50 gpm (2 to 3 L/S) at 50 psig. There may be also additional cooling water requirements.

Cold Weather Operation

Cold weather operation provides some additional constraints on mobility. If water is to be used for cooling and scrubbing, there is the possibility of damage during freezing weather. Enclosures may have to be provided for those vessels and pipes that have the potential for damage due to total malfunction during inclement weather. Protection of personnel will also be necessary.

Destruction Efficiency

Performance of hazardous waste destructors is normally measured in terms of destruction efficiency (DE) or destruction and removal efficiency (DRE).

Destruction efficiency refers to the percentage of hazardous constituents destroyed in the combustion chamber, while destruction and removal efficiency accounts for both the destruction and removal of the remaining original hazardous constituents by air pollution control equipment. The U.S. E.P.A. regulations require a destruction efficiency of at least 99.99% for the most principal organic hazardous constituents. The destruction and removal efficiency of polychlorinated biphenyls (PCB's), dioxins and dibensofurans is 99.9999%. The mass emission of these components from the incinerator will be less than 0.001g per kilogram introduced as feed. For alternative technologies, the U.S. E.P.A. is developing standards for these processes similar to those of waste incinerators.

Technical Feasibility

The largest commercially transportable unit has a capacity of 20 million BTU/hr, equivalent to roughly 11,000 tonnes/yr. of wastes (6,000 BTU/lb LHV) when operating at a fixed site.

This capacity is based on 7,000 operating hours with sufficient downtime for refractory replacement once per year (50 - 60 days). If the transportable unit is moved once a year, approximately one month will be required for dismantling at an existing site followed by setting up at a new site (not including an average of two or three days on the road). With proper scheduling, refractory replacement should take place during the dismantling or set-up period. It is estimated that the cost for each move would vary from $150,000 to $200,000.

Operating Costs

Operating costs for mobile units can be estimated based on the experience in operation of the ENSCO and EPA units.

Operating labour is estimated to be sixteen persons (minimum) at a total annual cost (including overhead) of $50,000 each for a total of $800,000 per year.

Maintenance and labour is estimated to be an additional eight persons resulting in an annual cost of $400,000.

Table 2

COMPARISON OF MOBILE INCINERATORS

	ENSCO	M & S ENG.	EPA UNIT	ROCKWELL	CONT. ENV. SYSTEMS	WESTINGHOUSE
Type of Unit	Rotary Kiln MWP-2000	Rotary Kiln	Rotary Kiln	Molten Salt Combustor	Rotary Kiln	Plasma Arc
Capacity	5t/h 20 x 10^6 BTU/h	40 x 10^6 BTU/h	1t/h 13 x 10^6BTU/h	100kg/h	10t/h	Prototype 240 kg/h Full Scale 1000 kg/
Capital* Cost	$4.0 M (US)	$4.0 M (US) Est. for large unit	$2-3 M (US) in 1982	Prototype avail. for $1 M (US)	Estimate $844k for Prototype	Full Scale Unit Est. $2.2 M (Can)
Operating Cost	To be calculated	Unknown	$17-18k/d	NA	NA	NA
Performance	80% On Stream	Preliminary Six nines DE	Mechanical Problems 52% On Stream	DE of Six 9's	Only on Oily Sand. No tail gas cleanup	Six nines on PCB
DE & Performance Guarantee	Guarantee 6-9's	NA	6-7 9's	Six 9's	NA	NA
Mobility	Trailer Mounted 6 trailers +5	Trailer Mounted	Residue Storage Problem Trailer Mounted 5 trailers + 6	Larger 1t/d unit Not Mobile	Trailer Mounted	Trailer Mounted
Delivery Time	6 months	8 months	1 - 2 years	Prototype avail. for sale	42 weeks	Westinghouse says six months

* Capital costs are generally as quoted by the supplier.

Table 2 cont'd

	ENSCO	M & S ENG.	EPA UNIT	ROCKWELL	CONT. ENV. SYSTEMS	WESTINGHOUSE
Staff Requirements	21 16 Op./1 Maint.	Operations only 2 men/shift	35 16 Op/15 Maint.	NA	NA	3 Operators/shift
Turndown Rate	Not Significant	Not Significant	Not Significant	Not Significant	NA	NA
Technical Backup	Very Good, Design Startup & Operat. Experience	Unknown	EPA probably not interested in providing	Rockwell not interested in further develop.	Unknown	Good
Utilities	400 kVA and water	Diesel Generator Plant	Diesel Generator Plant	NA	Unknown	1.5 MW electrical power
Ownership/ Lic.Arrangmt	Will sell outright with guarantee	Units sold by M & S Eng.	Will provide Dwg.	Rockwell wish to licence Develop.	Unknown	Lease unit rather than sell
Limitation Waste Types	Solids, liquids sludges & aqueous drums shredded	Solids, liquids & sludges	Solids, liquids sludges & aqueous. Drums shredded	Solids, liquids & sludges. Less than 20% ash	Solids, sludges & liquids	Only pumpable waste (liquid & sludges)

Staff is estimated to be four persons at an annual cost of $200,000.

Maintenance materials are estimated to be equal to maintenance labour or $400,000 per year.

For operating supplies $180,000 is estimated for fuel (10 Million BTU/hr) and $680,000 for caustic. These quantities relate to the situation of the destruction of PCB`s where the waste has a chloride content of about eight percent.

Insurance and tax are estimated to be 2% of the capital cost of $7 Million.

Overhead is estimated to be 10% of the total of all other out of pocket costs or $280,000.

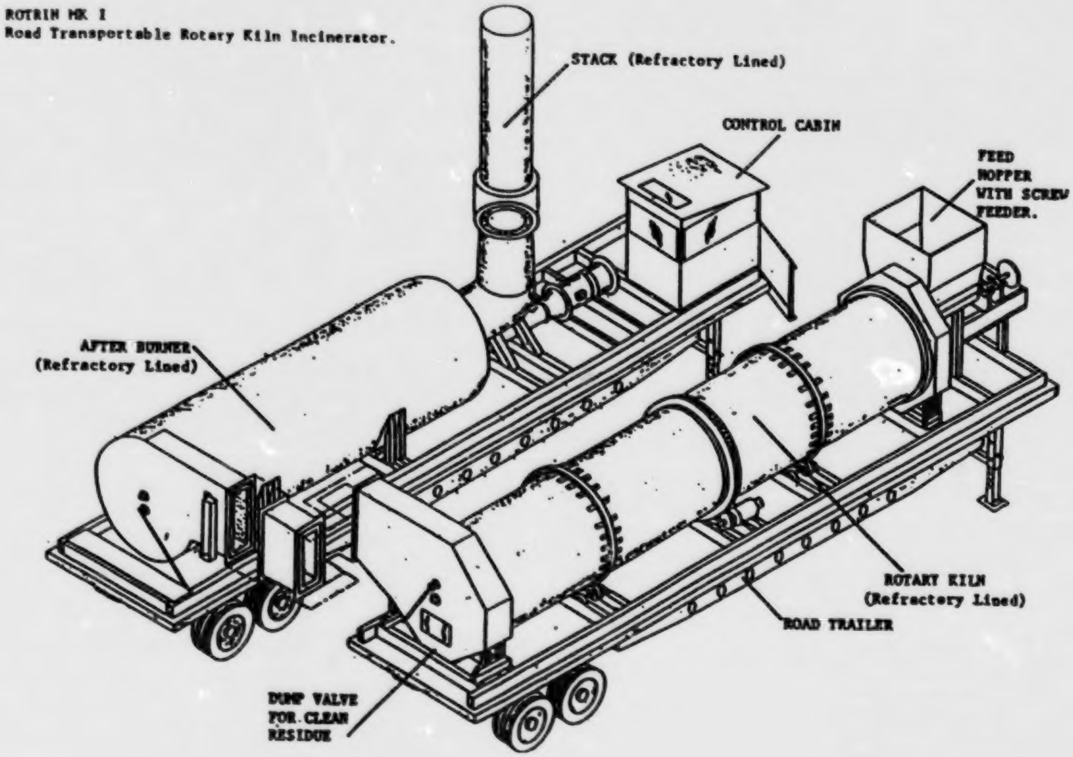
In summary, the estimated annual operating cost is:

Operating Labour	800,000
Maintenance Labour	400,000
Supervision and Staff	200,000
Maintenance Supplies	400,000
Operating Supplies	880,000
Insurance and Tax	140,000
Overhead	280,000
TOTAL	$3,100,000

The following is a brief description of established commercial technologies available for mobile destruction out of the many currently available. While these units are technically feasible and will probably will meet regulatory emission standards, siting of these units will become a major and perhaps overriding factor in any decision to acquire this type of facility for hazardous waste destruction.

CONTINENTAL ENVIRONMENTAL SYSTEMS LTD.

The Rotrin Mk I is a prototype incinerator that has processed oily wastes at a capacity of 8-9 tonnes per hour. The mobile rotary kiln can burn a variety of oily wastes. The maximum temperature is the result of the oil content of the waste. Continental Environmental Systems Ltd. are proposing to make a number of changes to the kiln to make for a more reliable and efficient process.



ROTRIN MK I
Road Transportable Rotary Kiln Incinerator.

STACK (Refractory Lined)
CONTROL CABIN
FEED HOPPER WITH SCREW FEEDER.
AFTER BURNER (Refractory Lined)
ROTARY KILN (Refractory Lined)
ROAD TRAILER
DUMP VALVE FOR CLEAN RESIDUE

The system consists of a refractory lined kiln with a feed hopper and a screw feeder located on a road trailer. There is a dump valve for clean residue at the end of the kiln. The refractory lined after burner is located on another road trailer. The ancillary equipment consists of a refractory lined stack and control cabin.

A prototype unit was developed by Bennett Environmental Consultants Ltd., Vancouver, under a grant from the Federal Government (E.D.P. Program). The unit was tested and sold to Esso Resources Canada Ltd. to burn oily wastes at the Cold Lake operations.

In operation, oily material is loaded into a hopper which is fixed to one end of the rotating kiln. A conveyer may be required to facilitate loading the hopper. A screw conveyer at the bottom of the hopper feeds the rotating kiln at a controlled rate. The rotation speed of the kiln is also controlled.

This unit is unproven for incineration of hazardous wastes.

ENSCO ENVIRONMENTAL SERVICES

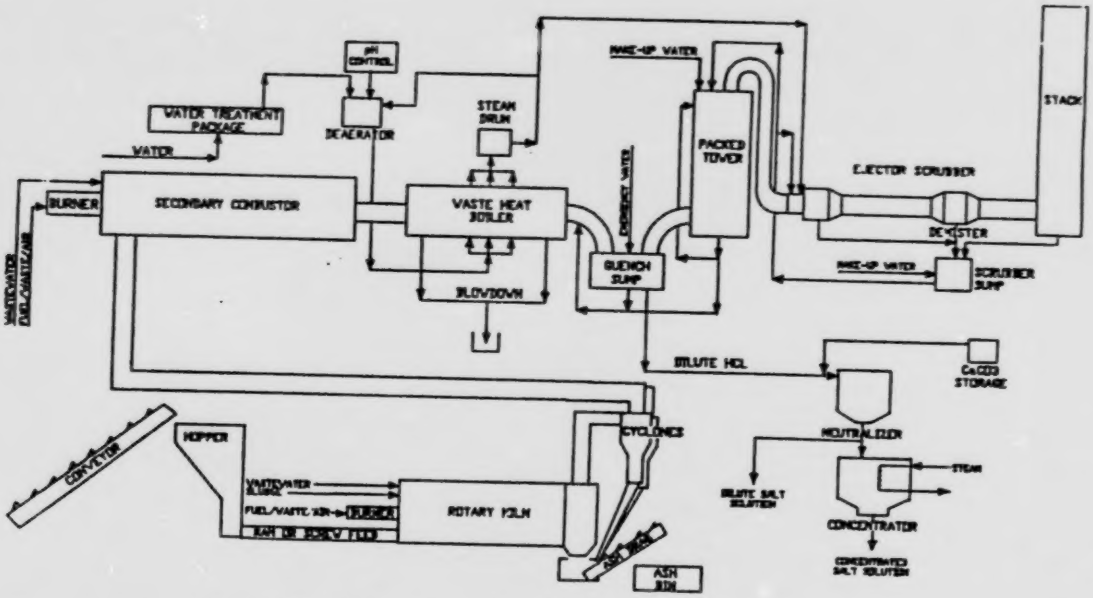
ENSCO builds a modular incinerator system mounted on five or six trailers designed to destroy semi-solid, solid and liquid hazardous wastes. It is a fully state-of-the-art incinerator designed to handle up to 36,000 gallons U.S. (16 tonnes) per day. The system is also designed to feed up to 8,000 lbs/hr (3.6 tonnes/hr) of solid wastes.

The principal components of the system are:

(1) A rotary kiln
(2) Secondary combustion chamber
(3) Air pollution control train consisting of a quench system, packed tower, ejector scrubber and stock
(4) Process control and chemical laboratory

The solid-waste feed system, normally tailored to a specific job, consists of an enclosed conveyor which carries wastes from the solid waste preparation system to a covered hopper which discharges to a ram feed or a screw feed unit.

The waste water feed system consists of a flat-spray nozzle which introduces waste in a horizontal spray into the kiln. Liquid combustible wastes can be used as an auxiliary fuel and introduced through the kiln burner. The sludge feed system consists of a sludge injection nozzle which sprays pumpable sludges into the kiln.


pH CONTROL
WATER TREATMENT PACKAGE
DEAERATOR
WATER
STEAM DRUM
MAKE-UP WATER
PACKED TOWER
STACK
EJECTOR SCRUBBER
BURNER
SECONDARY COMBUSTOR
WASTE HEAT BOILER
EMERGENCY WATER
QUENCH SUMP
DEMISTER
MAKE-UP WATER
SCRUBBER SUMP
BLOWDOWN
WASTEWATER
FUEL/WASTE/AIR
DILUTE HCL
CaCO3 STORAGE
CYCLONES
NEUTRALIZER
HOPPER
CONVEYOR
WASTEWATER SLUDGE
FUEL/WASTE AIR
BURNER
RAM OR SCREW FEED
ROTARY KILN
STEAM
DILUTE SALT SOLUTION
CONCENTRATOR
CONCENTRATED SALT SOLUTION
ASH DRAG
ASH BIN

SCHEMATIC FLOW DIAGRAM OF MWP-2000

The rotary kiln is a carbon steel cylinder mounted horizontally on a flat-bed trailer. The first ten feet of the kiln are lined with either insulating fire brick or rammed refractory. The kiln is mounted so that it can be inclined from 2 to 6 degrees and is rotated by a hydraulically controlled trunnion mechanism that can rotate the kiln from 1/2 to 2 revolutions per minute. Two cyclones are installed in the ductwork between the kiln and the secondary combustion chamber to remove lighter particulate matter.

The secondary combustion is designed to burn the gases discharged from the rotary kiln and to handle liquid wastes injected directly to this combustion. It is capable of burning waste waters injected through a waste water injection nozzle and also has an auxilary feed system for liquid combustible wastes.

The air pollution train consists of a quench system, a packed tower, and a ejector scrubber and stack. This equipment is capable of removing up to 1500 lbs/hr of HCl and particulate greater than 0.3 microns. A firetube boiler is provided to recover heat in the off gas from the two combustors. The waste heat boiler provides the steam required for the scrubber ejector system. The gases are drawn through the ejector mixing tube by the force of the steam delivered through a nozzle in the mixing tube. The turbulence created by the nozzle mixing tube design causes an agglomeration of submicron particles and the HCl in the water vapor supplied by the steam.

Provision is made for adjustment of pH by adding caustic into the recirculation line between the scrubber sump and the ejector scrubber to provide additional HCl removal capacity if a highly chlorinated material is burned at high rates.

The stack is fabricated of reinforced plastic. Condensate, formed in the stack, drains to the ejector scrubber sump. Stack gas temperature is measured by a thermocouple and the stack is also equipped with a system capable of continuously measuring the oxygen, carbon monoxide, carbon dioxide, hydrocarbon and oxides of nitrogen.

The laboratory and control room are located in a van trailer. The control room contains all the indicator readouts, control switches, data acquisition and control computer which are used to operate the incinerator.

The laboratory is equipped to conduct chemical and heating value analyses of the waste to be burned as well as the chemical analysis of the residues generated by the system. Analyses of samples of the effluent waste verify complete detoxification of the waste effluent streams prior to land filling or other disposal.

Several units are in operation currently burning sludges and hydrocarbons and some chlorinated hydrocarbons. These units have demonstrated the capability to destroy PCB's at a destruction and removal efficiency of greater than 99.9999%.

Ensco will either provide a turnkey operation or they will provide a fee-for-service basis for the treatment of waste.

M & S ENG. & MFG. CO., INC.

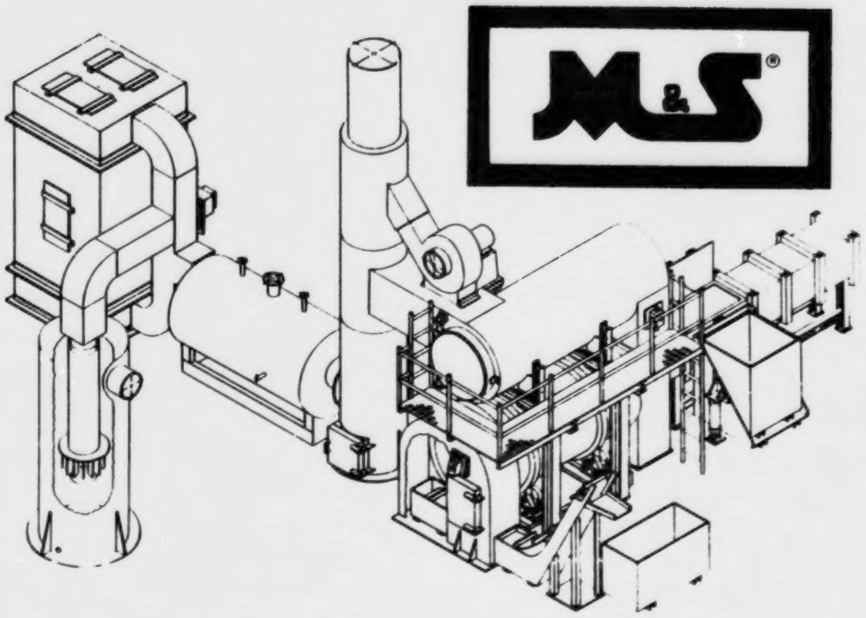
The M & S Engineering system consists of a rotary kiln incinerator designed, engineered and manufactured to suit each customer's particular circumstances. The system is capable of processing solids, liquids, sludges or a combination of all three. The required level of technology depends upon the type of waste being processed.

MKI systems are mounted on trailers that can be driven directly to the disposal site. The incinerators, available in capacities from 3 million BTU/HR to 40 million BTU/HR include the following:

(1) Rotary kiln incinerator
(2) Afterburner
(3) Flue gas cooler and waste heat boiler
(4) Baghouse filter for the removal of dry particulate
(5) Scrubbing system

Each mobile system includes an auxiliary trailer containing a control computer, sanitary facilities and operating personnel facilities. Larger systems are also available in transportable models.

There Mobile MKI Incinerator consists of a rotating ignition chamber and a stationary combustion chamber mounted on a flat bed trailer. A fabricated steel framework supports both chambers, which are constructed from welded steel plates lined with a castable refractory. The rotary ignition chamber refractory consists of a high density castable material providing an abrasion resistant surface with a maximum temperature rating of 2500°F (1370°C). The combustion chamber refractory is a medium density castable refractory capable of withstanding 2900°F (1600°C). A centrifical fan induces draft throughout the entire system.



When processing oversized solid materials which require reduction prior to feeding into the MKI Ignition chamber, a solids-waste shredder operating in conjunction with a gravity chute feeder is utilized. The solid waste shredder consists of a large sloped hopper constructed from heavy steel plates, a cutting chamber, a fan-cooled motor and a belt conveyer to the gravity chute feeder. Waste feed rates normally depend on the nature of the waste. For example, rates of 1000 kg/hour of soil with 800 ppm of PCB or 90 kg/hr of liquid can be achieved.

The hot gases enter a fine gas cooler or a waste heat boiler where they are precooled prior to entering the baghouse filter. The gases are cooled generating hot water and high pressure steam. A heat exchanger for cooling the exhaust gases and warming the incoming air is available.

The precooled gases from either the flue gas cooler, the waste heat boiler, or the heat exchanger enters a baghouse filter or a venturi scrubber where the particulate matter is removed. The venturi scrubber is effective in removing acidic constituents besides the particulate matter. If the venturi scrubber is used, a high efficiency demister is used before the gases are vented. A water conditioning system is required to treat the water used by the venturi scrubbing system.

All feeding devices are interlocked from operating when the temperature in either the ignition or combustion chamber falls below or rises above preset limits. System operation is computer controlled and the following setpoints are preprogrammed to allow operating while processing hazardous wastes.

- ignition chamber minimum temperature	760°C
- combustion chamber minimum temperature	1200°C

The computer controls the feed rate as required, depending upon a preprogrammed temperature signal. If the rate of increase of feed command is not effective, the computer will supplement the heat derived from burning waste by increasing the auxiliary burners.

Although the company reports a destruction efficiency of 99.9999% on PCB's and 99.99999% removal of dichlorobenzene, this unit is considered to be semi-proven technology.

WESTINGHOUSE (Pyrolysis Systems)

The Westinghouse plasma arc process uses electrical energy and a plasma flame to decompose organic compounds. The breakdown elements recombine into stable, simple compounds such as hydrogen, water, carbon dioxide and hydrogen chloride. The plasma arc reactor is refractory lined and operates at temperatures as high as 50,000°C. The plasma is generated by passing a pressurized gas through an electric arc. The torch acts as one electrode and the hearth at the bottom of the reactor acts as the other electrode. Waste feed materials are molecularly fractured by the hot ionized gas rather than chemically oxidized as in the incineration process.

Both pumpable solid and liquid wastes can be treated by this method. A water scrubber and cyclone are required to control particulates and acid emissions. Test results with this system have demonstrated at least 99.9999+% destruction efficiency. The unit can handle pumpable liquids, slurries and particles up to 20 to 30 mesh. Solid wastes require volatilization in a plasma cupula. The gases then pass into the plasma arc process.

The unit is fully mobile and fits into an enclosed 13-metre tractor-trailer unit.

The demonstration unit handles 4 kg of feed per minute while a large scale unit will handle up to 24 kg/minute. The state of the art torch electrodes have capacities ranging from 500kW to 10 MW of power. These units require a change of electrodes about every 200 hours. Power consumption is expected to be 2.7 kW/kg of feed. The Westinghouse unit may be considered to be an alternative technology, however its commercial operation has yet to be accepted.

ROCKWELL INTERNATIONAL

In the Rockwell International concept for molten salt destruction, organic material and air are continuously fed through a feeder beneath the surface of molten sodium carbonate at 800-1000°C. Solid combustible materials are pulverized to the required size in a hammer mill, conveyed into a hopper provided with a variable speed auger, and then introduced into the air stream for transport to the reaction vessel (combustor). The material is added such that only gaseous material formed during combustion is forced to pass through the melt before it is emitted into the atmosphere. The off gas containing carbon dioxide, steam, nitrogen, and unreacted oxygen, passes through refractory lined nozzles in the combustor head and is then scrubbed in a venturi scrubber or passes through a baghouse. The gases can be directed to an optional secondary combustion chamber.

Inorganic reaction products containing halogens, phosphorus, etc., along with excess sodium carbonate, must be removed at some point. This is to prevent complete conversion of the sodium carbonate in the combustor with any loss of acid pollutant removal capability. Any ash or inert solids introduced with the waste must be removed to preserve the fluidity of the melt. An ash concentration of about 20% is considered to provide an ample margin of safety for the melt fluidity. The melt can be removed continuously or on a batch basis. If the throughput is large, a side stream of the melt is withdrawn continuously. The melt can be quenched in water, filtered to remove the ash, and further processed to recover sodium carbonate.

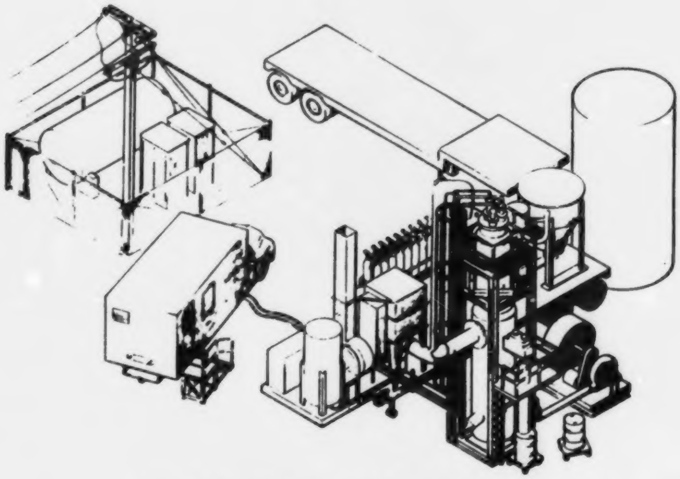
Sodium carbonate is compatible with the combustion products CO_2 and H_2O and reacts with the acidic components such as HCl and SO_2 forming the corresponding sodium salts. It is a material that is stable, non volatile, inexpensive and non-toxic. Combustion temperatures are sufficiently low as to prevent the formation of significant amounts of oxides of nitrogen. The system has been tested at rates of up to 260 lbs. (118 kg) per hour.

The Molten Salt Process possesses the ability to dispose of a great variety of wastes. In the tests performed on polycholorinated biphenyls (PCB's), no PCB's ($< 50\ \mu g/m^3$) were detected in the off gas samples even when all the carbonate had been converted to sodium chloride (Ref.). The extent of destruction exceeded 99.9999%. No organic material was detected in the off gas at temperatures as low as 700°C and residence times of the PCB in the salt as short as 0.5 seconds.

There are some wastes from an economic view point, for which the Molten Salt process is not particularly suited:

(1) Wastes with a high ash content 20% ash

(2) Municipal wastes and sludges and wastes for which less expensive processes are available



225 lb/hr MSD TRANSPORTABLE

Molten carbonate is known to be corrosive. The combustor is stainless steel and the dense alumina refractory are satisfactory materials for molten salt combustion.

The molten salt has an advantage over conventional incineration in that particulates and pollutant gases formed during combustion are absorbed or react with the salt and pollution abatement requirements are minimal. Organic wastes are also rapidly destroyed due to both the chemical and catalytic effect of the salt.

The molten salt demonstration unit was designed as a prototype of a portable unit and Rockwell are interesting in licensing the process to an organization interested in evaluating and completing its development.

EPA-ORD MOBILE INCINERATION SYSTEM

The EPA-ORD mobile incinerator was designed and constructed for the U.S. Environmental Protection Agency under contracts with MBA Associates, Mason & Hanger-Silas Mason Co. Inc. and IT Enviroscience. The Mobile Incinerator system consists of three major components:

(1) Combustion and air pollution abatement equipment mounted on three trailers

(2) Continuous flue gas monitoring equipment located on a fourth trailer

(3) Ancillary support systems

The first trailer is equipped with a control console, solids feeder, liquid and sludge feed ports, and a refractory lined rotary kiln. The incinerator is capable of processing 205 litres (1 drum of liquids) an hour or a solid feed rate of 1000 to 3200 kg/hr.

The trailer's frame in itself is the kiln's primary foundation base. The trailer structure is over 14 metres and was constructed in a box beam fashion with bulk heads to reduce torqueing. The trailer deviated from normal designs because it requires three axles to accommodate the road bed weight restrictions. The trailer was also equipped with a full air ride suspension system to reduce shock loads during transport.

Shredded solid materials are ramfed into the kiln, sludges and viscous fluids are pumped into the kiln, and liquids are atomized using air or steam. The kiln operates with excess air at temperatures as high as 1000°C. During the processing of sludges and solids, residual ash and inert solids are removed continuously from the discharge end of the kiln. Partially destroyed compounds and vaporized toxic materials are carried by the exhaust gases into the secondary combustion chamber on the second trailer.

The design of the kiln required some unique considerations with regard to its mobility. Several basic design areas were analyzed which resulted in a specific and unique engineering design for over-the-road trailer mounted units.

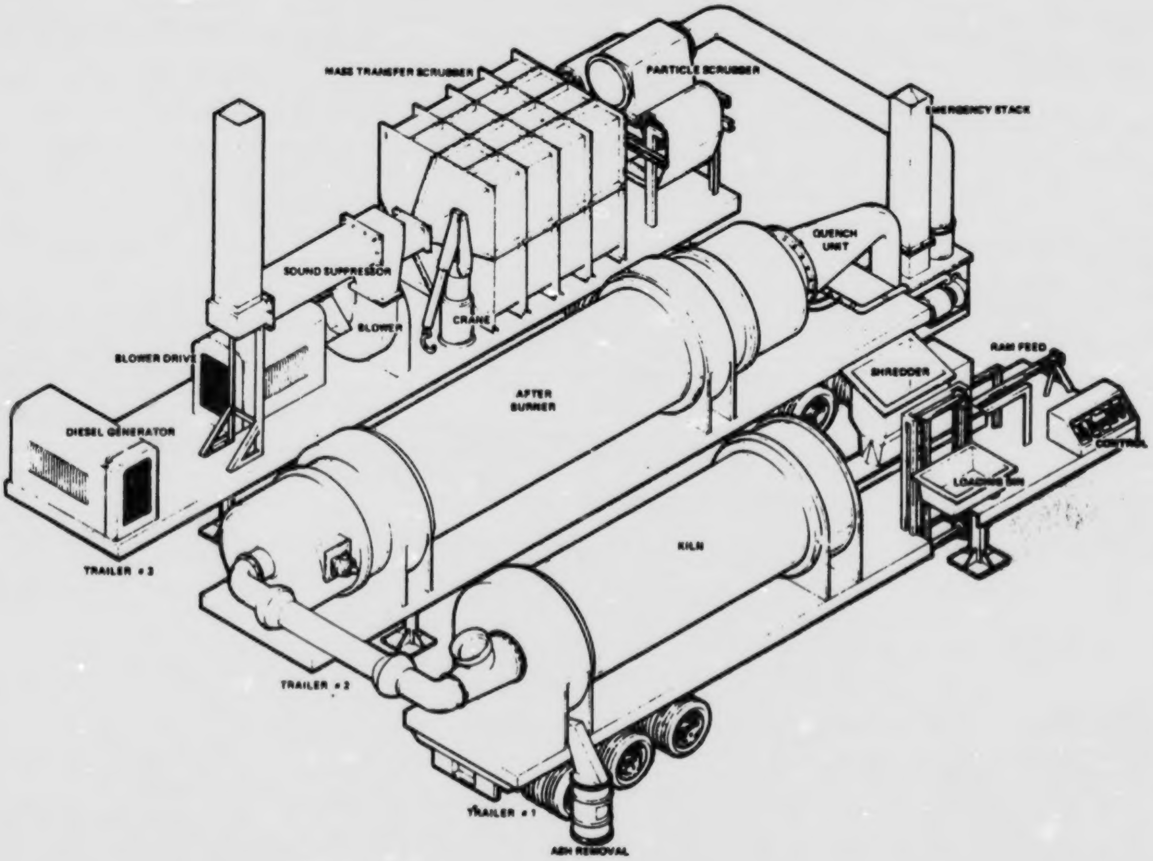
The secondary combustion chamber is very large relative to the rotary kiln and other equipment. This size was maximized to increase waste throughput at the 1200°C temperature and 2 seconds required by U.S. Federal regulators. This maximum through-put was of paramount importance in determining all other system size parameters. These conditions are sufficient to destroy PCB's, Dioxins and other stable organic substances. The flue gas flows through a venturi nozzle which is used to measure the residence time.

The third trailer consists of air pollution control facilities, equipment to cool the flue gas and to remove particulates and acid gases from the gas stream. Effluent gas stream clean-up is achieved by means of three sequentially arranged fundamental sub-systems.

- the quench unit and sump
- the particulate scrubber
- and the mass transfer scrubber

Each of these subsystems were selected, modified or specifically designed for the mobile concept.

Because the gas stream leaving the secondary combustion chamber is at 1200°C, the gases require cooling. The most effective mechanism to do so in the confined space associated with mobility is by water quenching.


MASS TRANSFER SCRUBBER
PARTICLE SCRUBBER
EMERGENCY STACK
QUENCH UNIT
SOUND SUPPRESSOR
BLOWER
CRANE
BLOWER DRIVE
RAM FEED
SHREDDER
AFTER BURNER
DIESEL GENERATOR
CONTROL
LOADING BIN
KILN
TRAILER # 3
TRAILER # 2
TRAILER # 1
ASH REMOVAL

The hot flue gas is cooled in a wetted-throat quench elbow. The design is special and unique in that it is a wetted throat venturi in the shape of an elbow, which is directly attached to the exit of the secondary combustion chamber and dumps directly to a ground level sump.

Flyash and submicron size particulate matter are removed by a Cleanable High Efficiency Air Filter (CHEAF). This specialized high-efficiency air filter was chosen primarily because it can remove sub-micron P_2O_5 particles expected during the incineration of organophosphates. The gases then pass through a packed bed scrubber where acid gases are removed. The flue gas is released to the atmosphere through a 40-foot stack.

A fully automated gas-sampling and dual analysis system is provided in another trailer, which incorporates gas-sampling pumps, gas analyzers, calibration gases, automated valves, and microprocessor controls. The monitoring system continuously draws gas samples from two locations: The secondary combustion chamber exit and at the stack. Analyses for O_2, CO_2, CO, SO_2, NO_x and total hydrocarbons are performed and the results are printed out at the computer terminal. The microprocessor control is connected to the incinerator safety interlock system and automatically and immediately stops the feeding of hazardous material if the concentration of the monitored components in the flue gas exceed acceptable levels.

The EPA-ORD incinerator system is presently located at the Denney Farm Site, Missouri. Destruction and removal efficiencies of greater than 99.9999% have been achieved. Test burns conducted with dioxin show that the EPA mobile incinerator performs well on either TCDD waste liquids or solids.

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INNOVATIVE WASTE TREATMENT TECHNOLOGIES AND THEIR IMPLEMENTATION"

Mr. Charles G. Daye
Chemical Wasste Management Inc.
Oak Brook, Illinois

Charles G. Daye

Paper unavailable at time of printing

OPERATING AND EMISSION GUIDELINES FOR MUNICIPAL SOLID WASTE INCINERATORS

EXECUTIVE SUMMARY

Presented to
The 10th Canadian Waste Management Conference
Winnipeg, 25-27 October, 1988

by
D.J. Hay
Chief, Urban Activities Division
Environment Canada

INCINERATION AND MUNICIPAL SOLID WASTE DISPOSAL

Energy-from-Waste Incinerators

Garbage, and what to do with it, is a growing problem for Canadian municipalities.

Every year, Canadians throw out about two-thirds of a tonne of garbage each. Multiply that by more than 25 million people and it would fill a convoy of trucks stretching from Ottawa to Tokyo and back. Although programs to recycle and re-use waste help reduce the problem, we are still left with a lot of garbage and nowhere to put it.

Landfill sites filling up

Garbage, also called municipal solid waste (MSW), has traditionally been buried in landfill sites, but there are significant disadvantages to disposing of it in this way. Landfill sites are filling up quickly, and finding new sites is becoming increasingly difficult. The high costs of land and of site maintenance and monitoring are making landfill increasingly expensive.

Landfill can also have adverse effects on the environment. Many of the landfill sites now in use were not designed for the type of waste we now discard. Chemicals leached from the site can contaminate groundwater. Garbage attracts rodents and other animals, and also produces inflammable methane gas.

Incineration: An Attractive Alternative to Landfill

Canadian municipalities have begun to consider energy producing incinerators as one element in an overall waste management plan.

Of the 16 million tonnes of municipal solid waste produced in Canada every year, half is paper, which burns easily. Each tonne of garbage, when burned, can produce slightly more than the energy equivalent of one barrel of crude oil. At today's prices, that's worth about $350 million annually.

Well designed and properly operated energy-from-waste (EFW) incinerators, fired with MSW, could reduce the need for costly landfill sites. However, because many toxic chemicals are found in MSW or can be produced by incineration, there are strong reservations about emissions from these waste burning facilities and their potential effects on the environment and human health.

Developing guidelines

Recognizing both the potential growth of MSW incineration and the health and environment concerns associated with MSW incinerators, the Waste Committee of the Canadian Council of resource and Environment Ministers (CCREM) established a national committee under the chairmanship of Environment Canada to develop MSW incineration guidelines.

The recommendations for guidelines contained in the committee's report address a range of issues from design to operations and record-keeping and should be considered as minimum requirements applicable to all facilities. Site-specific considerations that require particular attention will mean that individual jurisdictions may need to adopt additional design requirements.

The report recognizes the important role that reduction, reçovery, recycling and re-use can play in the management of MSW. The committee encourages all municipalities to evaluate these programs in their communities before embarking on an EFW project.

RECOMMENDATIONS

Size of Facility

Communities are encouraged to develop larger, centralized facilities in order to make MSW incinerators as cost effective as possible and to minimize emissions. The number of small facilities in an area should be limited.

New small scale residential, commercial and institutional incinerators that are not capable of meeting minimum combustion requirements should not be built. Existing systems that cannot meet minimum standards should be phased out, and pit burners should be banned for MSW disposal.

Combustion Technology

Complete combustion depends on thorough mixing of air and fuel in the incinerator. The incinerator must incorporate appropriate design and operating features that will allow air combustible gases sufficient time to mix fully and burn. Meeting these design and operating standards should minimize trace organic emissions and ensure good combustion.

Air Pollution Control

Air pollution control systems operating at low temperatures, combined with efficient removal of particulate matter, result in low emissions of trace metallic and organic species. Guidelines are proposed for fabric filter inlet temperature (140°C) and the degree of stack opacity (< 5%) which confirms efficient removal of particulate matter.

Control of Releases

The source of release by MSW incinerators are flue gases, ash residues from combustion and emission control, and wastewater.

Flue Gases

A good post-combustion control system is necessary to reduce emission levels. The limits proposed for hydrochloric acid (HCl) and particulates can be met with the best demonstrated control technology: acid-gas scrubber systems equipped with fabric filters. The following are the recommendations for stack discharge limits:

Stack Discharge Limits @ 11% O_2

Contaminant	Limit
Particulate Matter	20 mg/Rm^3
Hydrogen Chloride (HCl)	75 mg/Rm^3 (50 ppmdv) or 90% removal*
Carbon Monoxide (CO)	57 mg/Rm^3 (50 ppmdv)**
Total polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo-furans	0.5 ng/Rm^3*** (Toxic Equivalent Factor Basis)

* the less restrictive of these requirements shall apply

** refuse derived fuel systems shall maintain a limit of 114 mg/Rm^3 (100 ppmdv)

*** based upon isomer specific calculation. If only homologue analytical test data are available, the most conservative (largest) equivalency factor should be applied (New International Method).

For the combustion of normal municipal solid waste in facilities meeting the above criteria, the guidelines also identify anticipated emission concentrations for an additional eleven contaminants or family of contaminants.

Ash Management

General recommendations have been presented for the management of ash residues. These include the recommendation that bottom ash should be collected and disposed of separately from fly ash and that fly ash should receive treatment prior to land disposal.

Wastewater

Wastewater discharges from MSW incinerators should be eliminated. Where necessary, wastewater should be treated in compliance with provincial or municipal limits.

Monitoring

There are three basic monitoring requirements:

Process Monitoring - measures combustion performance; monitors should be capable of signalling poor operation so that corrective action can be taken or the incinerator shut down as soon as possible.

Stack Monitoring - opacity and HCl should be measured by continuous monitors equipped with alarm setpoints determined in consultation with the local jurisdiction.

Background or pre-construction monitoring should be conducted at the proposed location of an incinerator. The scope of this monitoring should be set by the local jurisdiction.

General Operating Procedures

Guidelines have been developed for general operating procedures.

- A minimum temperature of 1,000 degrees C should be attained before incineration starts and maintained during incineration.

- All facilities should be equipped with an automatic control system to stop waste feeding into the incinerator during upset conditions.
- The owner of the facility should have a plan for dealing with spills and other discharges that may occur on the site.
- There should be daily inspection to detect leakage, spills, corrosion, hot spots and malfunctions. The operator of the facility should keep records of all inspections.
- Operators should be properly trained and the owner of the incinerator should provide documentation to that effect.
- Stack emissions should be tested during normal operation of the waste incineration facility within six months of full normal operation, and as required by regulatory authorities. The pollutants to be tested are set out in detail in the guidelines.

A Social Benefit-Cost Analysis Framework for Analyzing Public Investments In Energy-From-Waste Facilities

Timothy L. McDaniels
McDaniels Research Ltd.

Cary Swoveland
Quantalytics Inc.

Introduction

Canadian communities dispose of roughly 16 million tonnes of municipal solid waste (MSW) annually. Of this total, about 1.4 million tonnes of refuse per year are incinerated; minor amounts are disposed of by other means such as open burning or composting. The remainder, about 14.6 million tonnes of MSW per year, is disposed of in some type of landfill. The recoverable energy potentially available in this landfilled refuse is enormous: it amounts to approximately 100 petajoules per year, or about 17.5 million barrels of oil, burned in oil-fired boilers.

Several factors have combined to raise public interest in the disposition of this municipal waste stream. First, there appears to be growing public awareness of the need to conserve energy and resources. Second, public acceptance and availability of space for new landfills appear to be diminishing. These trends, combined with expectations for increasing fossil fuel prices over the next decade, have prompted many municipalities across Canada to begin considering the viability of constructing energy-from-waste (EFW) facilities in conjunction with existing or new landfills.

The decisions faced by these municipalities are complex. At first glance, EFW facilities sound like a version of modern day alchemy: garbage is turned into a useful energy project, and problems regarding landfills are solved at the same time. As any experienced municipal waste planner knows, the problem is not nearly as simple as it may appear. EFW facilities involve extremely high capital costs that must be financed over time in part with the benefits from the energy produced. Finding a buyer for the energy is a complex process itself, as is the negotiation process for determining the appropriate price for the energy to be sold. Complex questions also arise in terms of effects on landfills. It has to be recognized that all EFW facilities must be operated in conjunction with (not in place of) landfills. About 25 percent of the total waste stream that enters an EFW facility must be landfilled as either ash or non-combustibles; in addition, there are times when the EFW facility is closed down for maintenance, and during those periods, landfilling is mandatory. Still more questions arise regarding the environmental effects of these two kinds of facilities. EFW plants have been shown to be the source of dioxin air emissions; landfills can be the source of noise, odour, visual pollution, and leachate into groundwaters. In sum, the decision to construct an EFW facility needs careful analysis that considers diverse ranges of values, including the value of energy produced and the value of landfill costs avoided, while also paying close attention to the different types of environmental costs associated with two facilities, and the effects on landfill costs of operating an EFW facility.

Insight into these complex social decisions can be gained through the use of social benefit-cost analysis. Social benefit-cost analysis is an applied welfare economics approach to analysis of the benefits and costs to society as a whole of a given policy, public investment, or regulatory change. Over the past two decades, many academic treatments of the conceptual issues of benefit-cost analysis (e.g., Mishan, 1983), as well as applied guide books on the practice of this method (e.g., Treasury Board, 1976) have been prepared. Social benefit cost analysis is now widely used in both the United States and Canada, as a decision making framework for investigating a whole range of public investment alternatives.

The paper reports on a conceptual framework involving the use of social benefit-cost analysis to analyze the benefits and costs of EFW facilities, including the changes that these facilities effect in landfill costs. This conceptual framework was developed for and serves as the basis of two major studies undertaken by the authors for Energy, Mines and Resources Canada. One study presents the results of a benefit-cost analysis of hypothetical EFW facilities in 35 municipalities across Canada (Quantalytics and McDaniels Research, 1988); the second study considers the social costs of landfills at six major municipalities across Canada and the effects of these social costs on the viability of the EFW facilities (McDaniels Research Ltd., 1987). The detailed results of those two reports are not presented here. Rather, an example is presented that illustrates the methods adopted in the two reports.

This paper is organized in the following manner. The next section provides a brief overview of social benefit-cost analysis in broad terms. After that, the situation of a municipality facing decisions regarding an EFW facility is considered. Then a method is presented for undertaking the social benefit-cost analysis of the EFW facility. The following section deals explicitly with how the social costs of landfills are calculated as input into the EFW benefit-cost analysis. The final section provides an example calculation of benefits and costs.

Social Benefit-Cost Analysis: An Overview

Social benefit-cost is an analytical tool for determining the aggregate effects on society as a whole of a particular public policy change. It appears superficially similar to private sector financial analysis involving discounted cash flows. However, social benefit-cost analysis differs from private financial analysis in a number of fundamental respects:

- Social benefit-cost analysis (SBCA) is undertaken from the perspective society as a whole, rather than from that of a private individual or investor.
- All measures of benefits in SBCA should reflect society's willingness-to-pay for the particular good in question (or consumption opportunities created). Willingness-to-pay is taken as a measure of the minimal social benefit for goods for which market values are available. If market values are not available, because the good is one that is not conventionally traded in markets (e.g., environmental quality), than values must be inferred indirectly.
- Costs are measured in SBCA on the basis of the value of opportunities foregone, or the value of opportunity costs associated with the resources needed for the particular activity.
- The discount rate for the analysis should reflect the social rate of time preference rather than the private rate of borrowing.
- In principal, all relevant benefits and costs occurring within society should be enumerated in the analysis; in practice, this is often difficult, but a comprehensive approach is the aim.

The basic approach of SBCA is to enumerate, in a manner similar to cash flows, the flow of social benefits and social costs over time that are associated with a given activity. Then discount rates are employed to determine the net present value of the given proposal. Another decision criterion or indicator that may be employed is the benefit-cost ratio.

Benefit-Cost Analysis as Applied to an EFW Proposal

We now explain how social benefit-cost analysis can be applied to evaluate the benefits and costs of a given EFW proposal. This discussion draws heavily on the approach of a study undertaken by the authors for Energy, Mines and Resources Canada, which estimates the benefits and costs of new EFW facilities in 34 Canadian communities (Quantalytics and McDaniels Research, 1988). Figure 1 summarizes the types of benefits that are associated with an EFW proposal, as well as the costs. The figure also indicates how these benefits and costs are handled in this analytical approach.

Because operation of an EFW facility necessarily requires ongoing operation of landfills as well, the appropriate approach to analyzing an EFW facility is from the perspective of the waste management system as a whole. The appropriate comparison is based on the total societal cost of refuse disposal for the community, with and without the assumed new EFW facility. The "without EFW" case analyzes disposal costs for the existing (or planned) waste disposal system, based on landfills and, in a few cases, on an existing EFW facility. The "with EFW" case analyses disposal costs assuming an EFW facility is operated in conjunction with the existing or planned landfill system, net of any social benefits from electricity generation, steam production, or resource recovery operations. The difference in costs between the "without EFW" and "with EFW" cases shows the net change in total disposal costs due to construction of the hypothetical EFW facility. If the present value of the difference in net annual disposal costs (i.e., the "net present value" or "NPV") is positive, it indicates the investment in an EFW facility is desirable from a public point of view.

Figure 1

Types of Benefits and Costs Associated with EFW Facilities

Category	Measurement Technique
BENEFITS	
Energy production	Social values of purchased fuel savings
Reduced social costs of landfills	Based on estimates of long term incremental costs of a landfill incorporating "best available control technology" ("BACT")
Materials recovery	Market value of salvaged materials
Reduced transport costs	Estimated change in transport costs, based in part on social values of purchased fuels
COSTS	
Capital costs	Market values
Operating costs	Market values
Social costs of EFW air emissions	Alternatives discussed in text

Figure 2 shows graphically what is considered in the "without EFW" and "with EFW" cases. Quantalytics and McDaniels Research (1988) contains an appendix with a detailed description of the modelling assumptions, methods of analysis and computer models.

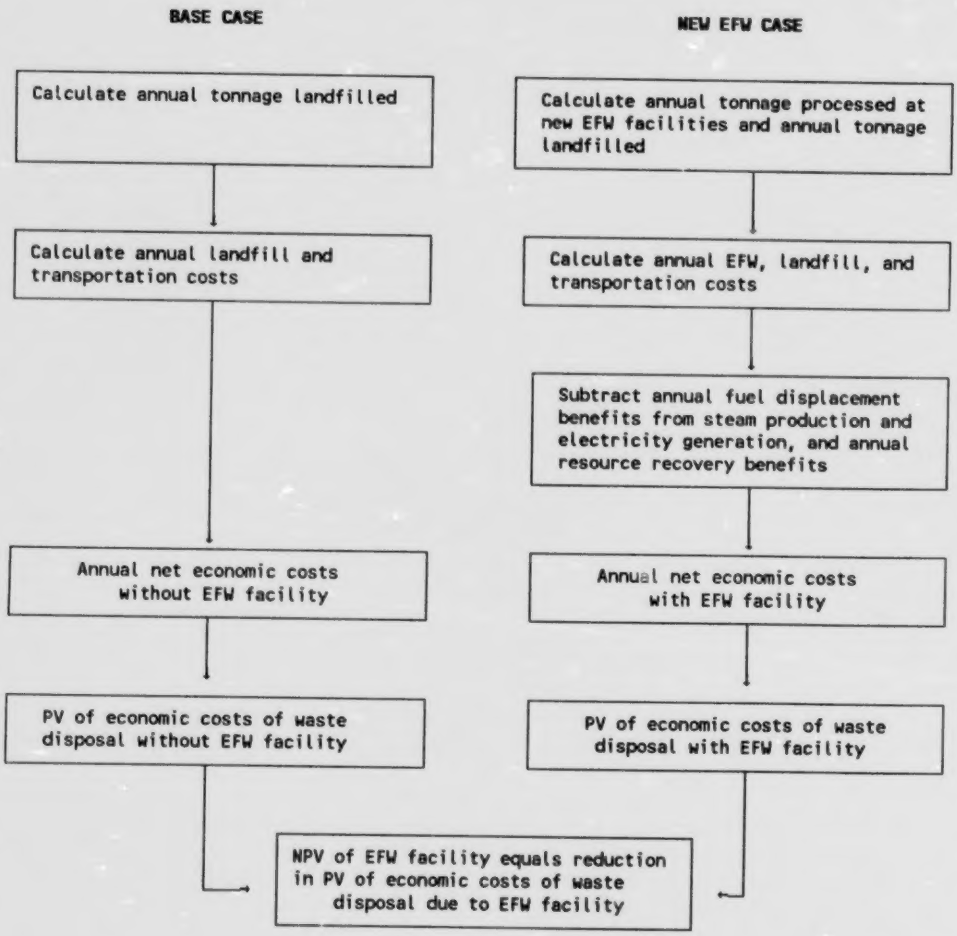
The main differences between this social benefit-cost approach and a financial assessment concern the values of displaced fuels and the discount rate. In a financial analysis, fuel costs saved would be based on forecast market prices, including all applicable taxes; in the social benefit-cost approach, fuel values should reflect social opportunity values, which generally equal marginal costs of production. Differences between the social values and market prices would arise because of taxes, government administered prices, or similar factors.

In the social benefit-cost analysis, discounting is done using a social discount rate, recommended by Energy, Mines and Resources Canada to be 7% (in "real" terms; i.e., assuming no inflation in units costs or benefits). The discount rate used in a financial analysis would reflect a private internal rate of return that, in part, reflects financial risk.

In principal, the "externalities" of both landfills and EFW facilities should be quantified and incorporated into a social benefit-cost analysis. "Externalities" refers, in the jargon of the economist, to unpriced side effects of an activity that may be viewed as positive or negative by those affected. Landfills have negative external effects due to their potential adverse effects on surrounding land values, aesthetics, and health. EFW facilities have negative external effects largely due to air emissions that could possibly affect health and air quality, as well as to possible adverse effects on land values and aesthetics. As discussed in Quantalytics and McDaniels Research (1988), the consensus appears to be that EFW facilities pose smaller health threats than do landfills, and little or no adverse effects on land values or aesthetics. These effects will undoubtedly differ from case to case, and because they are extremely difficult to quantify, are rarely treated in benefit-cost analyses.

Figure 2

Schematic Diagram of Social Benefit/Cost Analysis


BASE CASE
NEW EFW CASE
Calculate annual tonnage landfilled
Calculate annual tonnage processed at new EFW facilities and annual tonnage landfilled
Calculate annual landfill and transportation costs
Calculate annual EFW, landfill, and transportation costs
Subtract annual fuel displacement benefits from steam production and electricity generation, and annual resource recovery benefits
Annual net economic costs without EFW facility
Annual net economic costs with EFW facility
PV of economic costs of waste disposal without EFW facility
PV of economic costs of waste disposal with EFW facility
NPV of EFW facility equals reduction in PV of economic costs of waste disposal due to EFW facility

We discuss methods of analyzing external effects of EFW facilities below. Approaches to evaluating the social costs of landfills are a particularly important component of the analysis, and so are discussed separately in the next section.

There are three alternatives to estimating the external social costs of an EFW project:

- undertake a risk analysis and an economic evaluation of possible health effects due to air emissions; or

- treat the social costs as a fixed charge or a parameter that can be varied in the analysis, and examine its importance through sensitivity analysis; or

- assume that stringent control techniques, proper boiler design, and an appropriate location will mean the social costs are minimal, and so can be ignored in the analysis.

We favour the second and third approaches, both of which are employed in Quantalytics and McDaniels Research (1988) and in McDaniels Research (1988). These approaches are illustrated in the example presented later in this paper.

Social Costs of Landfills

The marginal social opportunity costs of additional landfills are a crucial input to any social benefit-cost analysis of EFW options. These marginal landfill costs are the social value of resource costs associated with landfills that are avoided as a result of proceeding with EFW projects. A number of studies indicate the social costs of new landfills are perhaps the single most important factor affecting the attractiveness of EFW facilities. For example, a recent study of Eastern Canada bioenergy market potential, for which McDaniels Research undertook the economic and policy analysis components, demonstrates that avoided landfill costs have a drastic effect on an EFW project's financial and social viability (Cogeneration Associates, 1983). Similarly, a study by Combustion Engineering Corporation estimates that EFW project capacity will triple in the US in the next three years. According to an industry spokesperson, "the driving factor in this increase is a scarcity of landfills" (New York Times, 1986). Lastly, our EFW study demonstrated that some potential Canadian EFW projects could become viable if the full range of potential social costs of landfills were considered.

Two fundamental approaches that could be employed to estimate the social costs of landfills: the *direct* approach and the *indirect* approach:

- The *direct* approach involves an examination of the effects of landfills currently operating. One would have to first ascertain the market-based costs of land and facilities, and than also measure the quantity of litter, odour, groundwater contamination, and other pollution generated. One would then attempt to convert estimates of these physical effects into monetary values of environmental damage using several techniques developed for such purposes. These techniques would include contingent valuation (e.g., through questionnaires) or hedonic prices (statistical analysis) to determine the value of certain externalities. Potential health costs would be evaluated through risk analysis models involving dose, exposure, and response parameters, along with assumed values of the costs of premature death or disability.

- The *indirect* approach involves estimating the costs associated with building a new, environmentally-sound landfill. Here, one estimates the cost of preventing environmental damage, which then becomes a proxy measure for the damage itself. The costs of environmental controls are usually easier to estimate than the cost of damage they prevent, because control costs are quantified as specific engineering and construction costs. The key point is that the cost of eliminating environmental damage is not necessarily equal to the cost of the damage, were it to occur. However, if one makes the assumption that abatement is cost effective (i.e., that society should place controls on landfills because the benefits of damage avoided exceed the control costs), then pollution control costs place a **lower bound** on the value of damage avoided. Of course, the validity of this indirect approach also rests on the assumption that a state-of-the-art landfill with stringent controls would contain all environmental discharges and internalize all costs.

As discussed in detail in McDaniels Research (1988), the authors favour the latter approach. The chief reasons are that it is tractable and can provide reasonable estimates that are comparable for a number of locations.

To operationalize the indirect approach, a set of steps and assumptions are needed to draw together land costs, capital and operating costs, environmental control costs, and transport costs. Figure 3 provides a summary of the assumptions employed in McDaniels Research (1988) which provided the data used in the example in the following section.

Figure 3

Summary of Approaches for Estimating Social Opportunity Costs of Landfills

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Land Costs

- Obtain data from municipalities on financial costs of current and future land requirements for landfilling.
- Adjust financial costs where necessary to reflect current market data.
- Size landfill in each community.
- Assume adjacent properties decrease in value by 10% over life of landfill.
- Assume affected adjacent properties are equal in size and value to land required for facility.
- Assume landfill land and buffer zone have salvage value equal to 75% of original value.
- assume adjacent properties rebound to 95% of original value once landfill closes.
- Conduct sensitivity tests with respect to all land value assumptions.

Capital and Operating Costs

- Obtain data from municipalities on the capital and operating costs of existing landfills.
- Engineering consultant provides estimates of disaggregated capital and operating costs for new landfills (excluding land) assuming use of BACT.
- Conduct sensitivity tests.

Environmental Costs

- Assume 400 m buffer zone internalizes the external effects imposed by landfills; examine with sensitivity tests.

Transport Costs

- Obtain data from municipalities of financial costs per tonne/km, excluding collection.
- Use these as a reasonable measure of economic costs, with certain exceptions.
- No assessment of social costs of truck traffic in base case; examine with sensitivity tests.

Example Analysis

This section provides an example of benefit-cost analysis as applied to an EFW proposal for a hypothetical Canadian city. Before proceeding with the example, however, the factors that make EFW potentially attractive from a social benefit-cost perspective merit review.

Foremost among these is the growing unacceptability of landfills. High financial costs of new landfill sites, concerns over the potential health and safety effects of landfills (particularly due to dears over hazardous waste in old landfills), and a public unwillingness to accept landfills within anyone's neighbourhood have made landfills unattractive. This is particularly true in the United States, where the population density and high level of public adversity make siting new landfills a long and contentious task. For example, a recent study estimates that EFW capacity will triple in the US in the next three years, and continue to grow rapidly after that. Similar situations are beginning to arise in Canada. For example, one of the two EFW projects not under construction in Canada, in the Vancouver area, had as its impetus the unacceptability of new landfill sites in the Fraser Valley east of Vancouver.

A second factor that has created interest in EFW has been increasing energy costs. However, with the rapid decline in fossil fuel prices in 1986, the value of EFW as a source of process steam has declined. Yet, the sale of steam to a nearby industrial or institutional user has been viewed as a crucial factor in the viability of an EFW project.

Similarly, current electricity prices and the prospect of ongoing price increases make the potential for sales of electricity another key factor in the viability of EFW. Again, this factor is particularly important in the US, where electrical costs are typically much higher than in Canada, and federal legislation requires utilities to purchase surplus electricity from an EFW cogeneration plant at the utility's full "avoided cost."

The example benefit-cost calculations are shown in Figures 4, 5 and 6. Figure 4 shows that the proposed EFW facility would serve an area which in 1986 generated an estimated 230,000 tonnes of solid waste. The capacity of the facility is shown to be 452 tonnes per day, or 115,000 tonnes per year, which is one-half of the total annual solid waste generation. The estimated capital cost of this facility is $43 million, assuming that acid gas scrubbers would be provided. It was assumed that one-half of the capital costs would be incurred in each of the years 1988 and 1989, and that the facility would become operational in 1990. Except in a few communities where pre-feasibility studies of EFW facilities had been done, the capacity of the EFW facility was determined from a regression of capacity against population.

The estimated levelized cost of constructing and operating a landfill with "best available control technology" ("BACT") is shown in Figure 5. Naturally many of these costs would vary considerably from one community to the next. Land costs, in particular, can be much higher than $2.30 per levelized tonne shown for this example.

The benefits and costs of the example EFW facility are shown in Figure 6. The largest benefit by far is the value of displaced fuels. Here we assume that the displaced energy product would be heavy fuel oil, which would be the case in Atlantic Canada. In other parts of the country, the displaced fuel is likely to be natural gas, which generates a smaller economic benefit per tonne of waste than does heavy fuel oil. Landfill cost savings are computed from the levelized cost shown in Figure 5. The transportation cost savings depends on the locations of existing and new landfill sites, and of the EFW facility itself. Here, the transportation cost savings are very small. Benefits from resource recovery (ferrous metals only) are also shown to be small.

The economic costs of the EFW facility consists only of the capital and operating and maintenance cost of the EFW facility. In this example, the present value of these costs is $62.2 million, which compares with an undiscounted capital cost (from Figure 4) of $43.0 million. The difference between the present values of benefits and costs, net present value, is shown to be about $6.4 million, indicating that the project can be supported on economic grounds.

If landfill costs are based on conventional practice, rather than BACT, the present value of the landfill cost savings is reduced from about $20.1 million to $6.3 million, causing net present value to go from $6.3 million to *negative* $7.4 million. This $7.4 million deficit is equivalent to about $7.07 per tonne, on a levelized basis. This means that total benefits exceed total costs if and only if the externalities associated with landfills (net of any externalities associated with the EFW facility) *exceed* $7.07. The $7.07 figure can be thought of as a *break-even* value for landfill externalities.

Figure 4

Annual Solid Waste Generation and Size of Proposed EFW Facility

Current Tonnes Landfilled Annually	230,000
Daily Capacity of Proposed EFW Facility (tonnes)	452
Tonnes Incinerated Annually	115,000
Capital Cost of EFW Facility (1986 dollars)	$42,962,000

Figure 5

Example Calculation of Social Costs of Landfills (levelized cost per tonne, 1986 dollars, 7% discount rate)

Pre-development Costs	1.18
Land Cost Net of Salvage	2.30
Capital Cost	10.84
Operation & Maintenance Cost	4.43
Post-Closure Costs	.26
Reduction In Land Values	.24
Total Levelized Cost	**19.24**

Figure 6

Example Calculation of Discounted Benefits and Costs of EFW Facility (thousands of 1986 dollars, discounted at 7%)

Benefits	
Energy production	47,107
Landfill cost savings	20,107
Transportation cost savings	125
Resource recovery	1,306
Total Benefits	**68,645**
Costs	
Capital and O&M costs of EFW facility	62,200
Net Present Value	**6,445**

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STATUS OF R&D ACTIVITIES IN THE EUROPEAN ECONOMIC COMMUNITY

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BACKGROUND

Municipal solid waste (MSW) can be viewed either as a waste requiring disposal and/or as a source of energy and materials. In Europe, notably following the oil crisis in the early 1970's, it has increasingly been viewed as the latter, and many initiatives on local, National and European levels, have sought to utilise this resource. Many of these were hasty in conception, and the grander schemes for materials recycling and the production of fuel fractions have been significantly modified against a background of generally escalating costs and poor market penetration. National attitudes are evident, but public concern, the increasing cost/unavailability of landfill, and tightening standards of landfill operation, have generally restimulated interest in alternative means of disposal, and particularly in incineration. The future development of incineration, however, will be dominated by environmental impact issues, particularly gaseous emissions, dioxins, and ash/residues disposal, and stringent new European directives on gaseous emissions will seriously affect the economics of installing new capacity.

MSW INCINERATION IN EUROPE

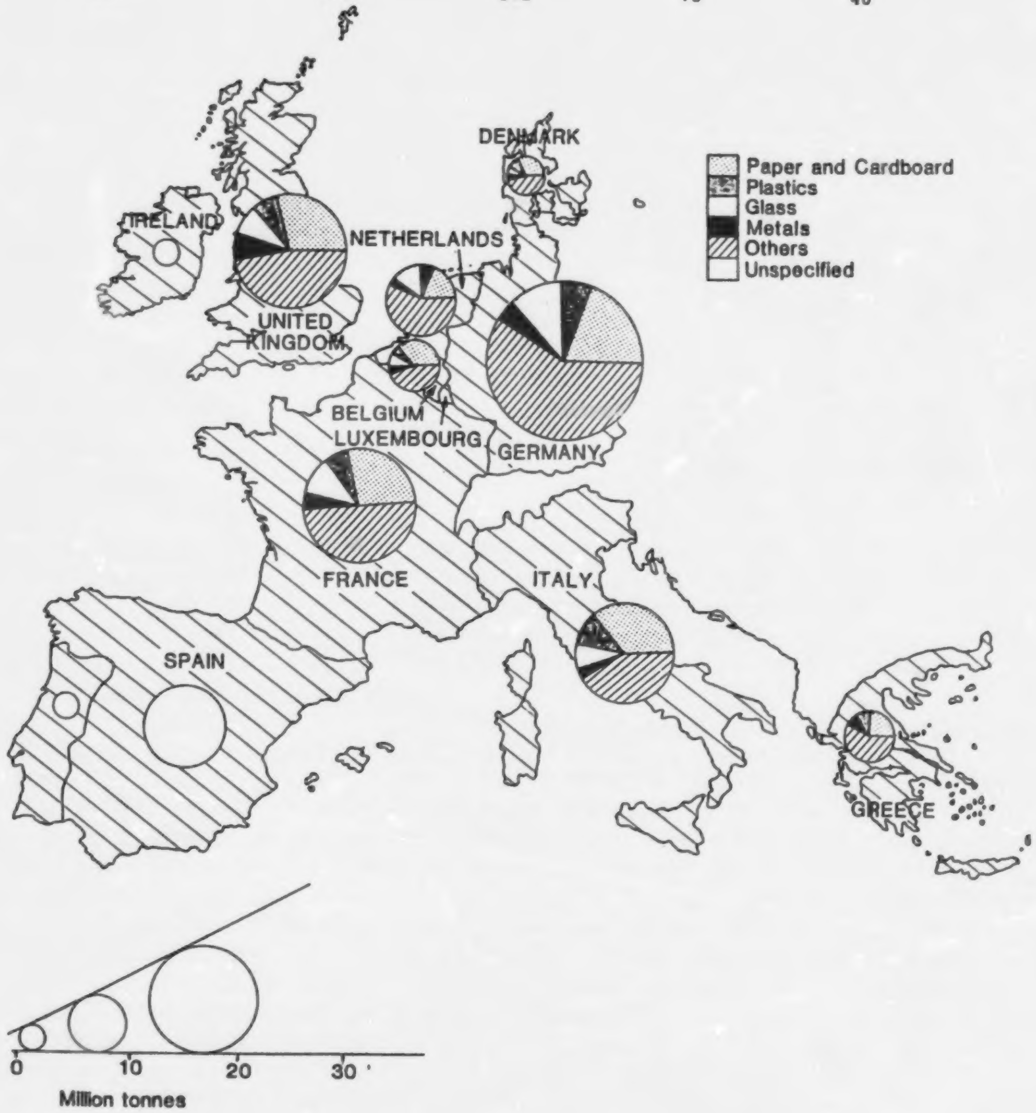
The 12 nations of the European Economic Community (EEC) produce some 400 to 500 Mte of industrial and municipal waste annually. Current estimates suggest municipal waste represents some 110 Mte of this, with the majority, over 75%, being derived from households. The composition, rate of generation, and fraction incinerated vary significantly between member countries (Figure 1), but overall some 25% is incinerated, 5% recycled, and the remainder landfilled.

About 525 incinerators are operated in the Community, 50% of which have a nominal capacity of 1 to 6 te/hr (CEC, 1987b). However, the bulk of the capacity is in larger incinerators, with 88% of MSW being burnt in plant larger than 6 te/hr. The exception here is France, where only 20% of the capacity is in >6 te/hr plant and where many Communes currently operate batch incineration on a less than 1 te/hr scale.

The smaller incinerators tend to operate without gas clean up. Overall 80% have some form, split equally between cyclones and electrostatic precipitators. However, the trend is towards improved heavy metal and acid gas removal and 7% of plant, predominantly in Germany, have scrubbing systems of one form or another. With tightening National legislation and proposed EEC emissions directives this proportion is set to rise significantly - partly through the closure of plants which prove uneconomic to retrofit with the required abatement equipment. The distribution of incineration plant is

FIGURE 1 SUMMARY OF MSW ARISINGS IN EEC COUNTRIES

MEMBER STATE	POPULATION (millions)	MSW PER CAPITA (kg/yr)	%INCINERATED	NO OF MSW INCINERATORS
Belgium	9.9	600	21	27
Denmark	5.1	490	66	48
France	54.6	288	43	260
Germany	61.0	447	35	45
Greece	9.9	404	-	1
Ireland	3.6	360	0	0
Italy	57.1	263	23	84
Luxembourg	0.4	514	77	1
Netherlands	14.5	503	31	11
Portugal	10.2	233	0	0
Spain	38.6	275	5	7
UK	56.1	312	10	40


DENMARK
Paper and Cardboard
Plastics
Glass
Metals
Others
Unspecified
IRELAND
NETHERLANDS
UNITED KINGDOM
BELGIUM
LUXEMBOURG
GERMANY
FRANCE
ITALY
SPAIN
GREECE
0
10
20
30
Million tonnes

Data for 1985 Sources: UN (1987), CEC (1987a), Woodfield (1987) therefore set to change, with large capacity plant with integral heat recovery and flue gas scrubbing becoming dominant. Sweden is pioneering much of this technology (Krol and Dent, 1987). A European example of such a plant is the 300,000 te/yr CHP incinerator commissioned in 1981 at Bielefeld, North Rhine Westphalia, Germany at a cost of £45M (30% of which was environmental protection). However, public resistance to such plant and the NIMBY syndrome is expected to strongly influence the replication of such schemes.

LEGISLATION ON MSW INCINERATION

Atmospheric emissions from European municipal waste incineration have been estimated by the EEC (CEC, 1987b) as:

	te/yr	%FROM >6 t/hr PLANT
Dust	28,000	56
Pb	570	70
Cd	31	73
Hg	68	87
HCl	144,000	85
HF	1150	86

These are predominantly attributed to the larger scale plant where the bulk of the material is burnt. Several countries have introduced or are introducing new legislation to reduce these figures, although their effect is largely still to be felt. Discussions on European wide legislation are also currently underway. The directives proposed for new plant (CEC 1987c) are summarised in Table 1. Directives for existing plant are also proposed (CEC 1987d), but all plant are proposed to meet the new plant directive on a 10 year time scale. The purpose of the directive is two-fold: to set strict limits for various classes of pollutants, and; to minimise the formation of dioxins by ensuring efficient combustion and adequate residence time. Continuous monitoring of key parameters is proposed to ensure the objectives are achieved.

EEC R&D PROGRAMMES IN RECYCLING AND ENERGY FROM WASTE

Initiatives and implementation of EEC policy are the preserve of the 22 Directorates of the European Commission (CEC). In the late 1970's both the Directorate General for Science, Research and Development (DG XII) and the Directorate General for Energy (DG XVII) launched major initiatives in waste recycling and utilisation with the objective of supporting the commercial demonstration of novel processes.

In the 9 years to 1987 1460 projects have been selected for support under the Energy Conservation programme (upto 40% funding), to a total of ca $Can 2500M, making this the largest programme of its type in the world (Fabry and Haines, 1988). In the sector Biomass and Energy from Waste (discussed by Davis and Ferrero, 1985) a total of 49 projects have been selected in the categories "Production of heat and energy by direct combustion" and "Production and utilisation of refuse derived fuels". Direct combustion predominantly relates

TABLE 1 DRAFT CEC DIRECTIVE FOR NEW MSW INCINERATOR PLANTS

COMBUSTION CONDITIONS:

Combustion temperature 850°C
Plant to be fitted with auxiliary burners to be automatically activated if temperature falls below limit
Gas residence time 2 seconds
Minimum oxygen 6%

EMISSION LIMITS, mg/m^3 at 273K, 101.3 kPa, 11% O_2 (or 9% CO_2), dry gas:

	PLANT >5te/hr	PLANT <5te/hr [1]	MONITORING [2]
Particulates	50	100	CONT
HCl	50	100	CONT
SO_2	300	300	INT
CO	100	100	CONT (daily average)
HF	2	4	INT
Total organic carbon	20	20	INT
Heavy Metals			
(Pb+Cr+Cu+Mn)	5	5	INT
Ni+As	1	1	INT
Hg	0.1	0.1	INT
Cd	0.1	0.1	INT

EXHAUST CONDITIONS:

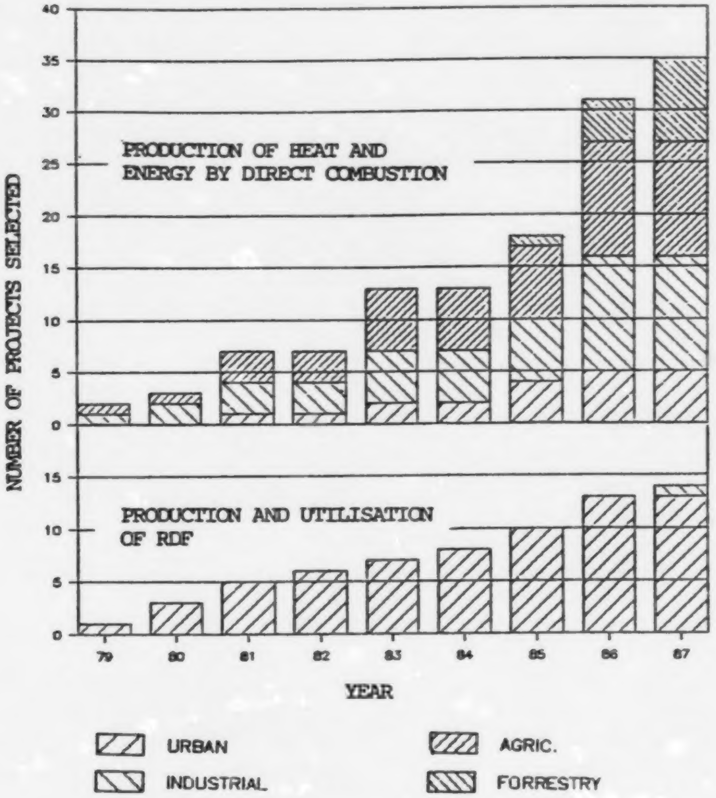
Stack gas temperature	CONT
Stack gas humidity	CONT

[1] Derogation may be given to plants <1 te/hr in areas subject to considerable seasonal variations
[2] INT: Intermittent monitoring.
CONT: Continuous monitoring. Monthly means must not exceed limit value. Daily averages must not exceed value by more than 30%.

to agricultural, industrial and forestry wastes. Urban refuse, however, dominates schemes for the production and utilisation of RDF (Figure 2). Revealing, however, is that of the 13 urban RDF projects selected 8 have since been cancelled, predominantly through economic non-viability and lack of external financial support (Fabry and Haines, 1988).

Under the DG XII 1st Recycling and Utilisation of Wastes Programme (1979-85) 7 projects on RDF production and utilisation have been completed (Table 2). However, in line with the DG XVII experience, European waste sorting effort is increasingly focussed on source separation and pre-sorting to reduce the contamination of recovered values (eg heavy metals in compost) rather than on the production of RDF.

FIGURE 2 CUMULATIVE DISTRIBUTION OF COMBUSTION PROJECTS SELECTED UNDER CEC DG XVII PROGRAMME



(AFTER FABRY AND HAINES, 1988)

TABLE 2 DGXII RECYCLING AND UTILISATION PROJECTS (1979-85)

RDF Preparation	7
RDF Combustion	1
RDF Gasification/Pyrolysis	2
Ind. Waste Combustion	1
Ind. Waste Gasification/Pyrolysis	2
MSW Gasification	1
Co-combustion of Wastes	1

RESEARCH AND DEVELOPMENT PROJECTS

European sorting and utilisation projects have been variously reviewed (Barton et al, 1985; Ferranti and Ferrero, 1985; Abert, 1985); Beukens (1985) discussed European technology for MSW incineration; and Bunsow and Dobberstein (1985, 1987) presented detailed data on the composition of, and emission from the combustion of, various European d-RDF's. A summary of the DG XVII projects is due from the CEC by the end of this year. UK and Swedish R&D has recently been reviewed as part of a collaborative IEA initiative (Dent et al, 1988; Krol and Dent, 1987 resp).

Emissions

As discussed above, emissions abatement (when practised has largely been restricted to simple dust arrestment using either cyclones or electrostatic precipitators. With tightening legislation, most countries are looking towards collaboration with Sweden for new abatement technologies. Germany, like Canada, is well down this road. These technologies have been extensively discussed elsewhere (Carlsson, 1986a/b; NITEP, 1986).

Research on an alternative to the conventional dry or semi-dry lime scrubbing system is being undertaken on a 16 te(steam)/hr CHP plant at Philips, Eindhoven (NL) under the CEC demonstration programme. The incinerator burns 110,000 te/yr of mixed commercial and sorted municipal waste (coarse RDF) plus some liquid waste. The abatement equipment consists of a conventional dry precipitator followed by a condensing wet scrubber. In this Flakt unit the gases are first reacted with dilute lime slurry (milk), then cooled to some 45°C by a cold water wash to remove residual gas phase heavy metals (eg. mercury). Water recycling and purification is used, and the recovered materials are disposed of with the grate and fly ash. All components are reported as being well below the proposed EEC limits (Keet, 1988).

Waste Sorting

Waste sorting was originally seen in Europe as a means of recovering values. Persistent problems of market penetration meant that it was subsequently seen more as a means of fuel production. Increasingly, pre-sorting and source separation is seen as a means of reducing combustion emissions (for example, of heavy metals through the removal of batteries) and enhancing the calorific value of the waste (although also used to enhance compost quality, particularly in the Netherlands). Barton and Scott (1988) report and increase in boiler efficiency from 55% to 63% in incineration trials with urban refuse screened at 40 mm screen in a trommel.

Although similar emission levels were reported on a g/kg burnt basis for the screened and unscreened refuse, it is anticipated that such improvements will enhance the economic viability of incineration. As such, the results of the forthcoming NITEP Mid-Connecticut are awaited with interest.

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MODERNISATION DE L'INCINÉRATEUR DE QUÉBEC

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INTRODUCTION

La région immédiate de Québec regroupe la Capitale et les douze (12) municipalités qui l'entourent. La population totale de cet ensemble est présentement de 471 000.

Un organisme régional créé en 1969 et appelé la Communauté urbaine de Québec dispense à cette population un certain nombre de services à caractère régional dont l'élimination des déchets.

Cette élimination est effectuée par le biais d'un incinérateur construit au début des années 70 et mis en opération en avril 1974.

Depuis 1978, nous faisons subir à cette usine des transformations très importantes visant l'amélioration du rendement de la combustion et de l'environnement.

Dans les quelques lignes qui suivent, nous allons décrire brièvement l'usine et son fonctionnement, de même que les modifications susceptibles de la rendre plus efficace et, dans la mesure du possible, non polluante.

Dans un second temps, il sera question des objectifs poursuivis et des résultats attendus ou déjà mesurés, aussi bien quant à l'efficacité de la combustion qu'à l'amélioration de l'environnement.

DESCRIPTION DE L'USINE

L'usine a été conçue pour incinérer 907 tonnes par jour de déchets solides municipaux et comprend quatre (4) fours-chaudières. Les fours sont de conception Von Roll. Les chaudières ont été dessinées et construites par Dominion-Bridge.

Les principales conditions théoriques d'opération de ces unités d'incinération sont présentées au tableau 1.

Communauté urbaine de Québec
Incinérateur Régional

TABLEAU 1

CONDITIONS THÉORIQUES D'OPÉRATION D'UN FOUR-CHAUDIÈRE

Capacité nominale d'incinération par jour: 9,5 tonnes/heure de déchets dont le pouvoir calorifique inférieur est de 12 560 kilojoules par kilogramme

Production de vapeur maximale : 36 800 kilogrammes par heure

Température de l'eau d'appoint : 142 degrés Celsius

Température de la vapeur : 315 degrés Celsius

Pression de la vapeur à la sortie de la chaudière : 4 689 kilopascals

Température de l'air de combustion à l'entrée : 15 degrés Celsius minimum

Température des gaz de combustion à la sortie de la chaudière : 250 degrés Celsius

Les composantes principales de l'usine dans sa conception originale sont les suivantes (voir figure 1):

1- Un quai de déchargement couvert et une fosse de réception pouvant contenir jusqu'à 2 700 tonnes de déchets;

2- Un système d'alimentation du four par voie de pont-roulant, trémie, table vibrante et goulotte refroidie à l'eau;

3- Un four dont le lit de combustion est constitué de trois (3) grilles inclinées du type Von Roll et dont la chambre de combustion est un foyer aquatubulaire à circulation naturelle, muni de murs-écrans à tubes suspendus à une charpente d'acier. Le four est pourvu d'un brûleur d'appoint au mazout et, en conséquence, le foyer est séparé en deux (2) zones par un mur-écran à tubes.

4- Une chaudière composée d'une section d'évaporation, d'une section de surchauffe, de deux autres sections d'évaporation et, enfin, d'une section "économiseur". Tous les tubes sont disposés verticalement par panneaux et sans chicane et leur nettoyage est assuré par un système de martelage.

5- Un électrofiltre à deux (2) champs qui assure le dépoussiérage des gaz de combustion.

6- Un ventilateur de tirage par four et une seule cheminée pour les quatre (4) lignes d'incinération.

7- Un système de convoyage des mâchefers et un autre pour les cendres volantes.

8- Une fosse où ces résidus sont accumulés jusqu'au moment de leur transport à un site d'enfouissement sanitaire.

9- Une conduite de transport de la vapeur vers l'usine de notre client exclusif, la Papeterie Reed, et une conduite de retour du condensat.

Depuis 1974, l'usine a fonctionné presque sans interruption. Nous y avons traité plus de 2 700 000 tonnes de déchets et avons vendu à la Papeterie Reed plus de 5 300 000 tonnes de vapeur.

Peut-on alors conclure que c'est une usine sans problème? Nous serions trop heureux qu'il en soit ainsi.

HISTORIQUE DES TRANSFORMATIONS

Quelques mois après la mise en opération de l'usine, l'incinérateur fut l'objet de plaintes des résidents du quartier environnant au sujet de retombées intermittentes de particules de papier non complètement brûlées (escarbilles). Ces retombées étaient particulièrement importantes durant la période de démarrage d'un four (puisque l'électrofiltre est alors inactif) et aussi lorsque afin de satisfaire à la demande de vapeur du client, nous étions obligés d'augmenter l'admission d'air primaire et/ou d'air secondaire, et ce de façon importante. La capacité d'épuration de l'électrofiltre était alors dépassée et son pouvoir déjà faible de retenir les grosses particules de papier non complètement brûlées était sérieusement diminué.

En 1978 et 1979, nous avons, une première fois, cherché à éliminer ce problème en modifiant la configuration du foyer ainsi que le système d'injection d'air secondaire (voir figures 2 et 3). Cette intervention a amélioré la combustion et réduit, de façon significative, les émissions de particules sans pourtant éliminer les retombées des escarbilles.

De par la nature des modifications, l'accrochage était prévisible. Cependant, un résultat un peu inattendu de ces travaux fut l'accroissement de la fréquence du phénomène de l'accrochage des cendres sur les parois de la chambre de combustion, juste au-dessus de la grille principale; ce qui a eu pour conséquence d'augmenter le nombre d'arrêts des fours pour fins de nettoyage et donc, par ricochet, celui des démarrages au cours desquels les retombées restaient importantes.

En 1985, nous avons donc revu toute la question pour en arriver à la décision de modifier à nouveau notre installation. Entre-temps, Environnement Canada nous avait proposé de réaliser la phase II de son programme PEENI (NITEP) sur un des fours de l'incinérateur. Trouvant que cette offre arrivait à point et qu'elle pouvait contribuer à la recherche de la meilleure solution, nous l'avons acceptée. Puis, à la suggestion d'Environnement Canada et de notre consultant le Consortium Roche/Lavalin, nous avons transformé un des quatre (4) fours de la façon suivante: (voir figure 4)

1- Contrôle de l'air primaire vers la grille de préséchage.

2- Répartition de l'air primaire sous la grille principale en six (6) zones distinctes.

3- Construction de dièdres à l'entrée de la chambre de rayonnement et augmentation du volume de cette dernière en vue d'une rétention prolongée des gaz.

4- Injection d'air secondaire au moyen de tuyères multiples installées dans les nouveaux dièdres.

5- Automatisation supplémentaire des commandes et des contrôles tels ceux relatifs à la vitesse des grilles et la mesure des débits de l'air de combustion primaire et secondaire, le tout asservi au débit de la vapeur, au niveau d'excès d'air et à la température des gaz de combustion.

Remis en marche depuis le printemps 1986, le four modifié a servi à la réalisation des essais PEENI. Pour notre part, constatant que nos objectifs étaient en bonne partie atteints, nous avons entrepris la transformation similaire des trois (3) autres fours en apportant les correctifs supplémentaires suivants:

1- Modification légère de la voute inférieure du foyer.

2- Nouvelle conception des tuyères d'injection d'air secondaire.

3- Prolongement des parois refroidies à l'eau jusqu'au niveau de la grille principale dans le but de réduire les accrochages des cendres en fusion.

Sachant que tout cela ne serait pas suffisant pour éliminer complètement les émissions d'escarbilles et pour réduire à un niveau tolérable les émissions de gaz acides, des métaux lourds et des polluants organiques dans les gaz de combustion, nous avons pris la décision de compléter la modernisation de l'usine en ajoutant après les électrofiltres, des équipements d'épuration considérés actuellement comme étant les plus performants sur le marché. Suite à un appel d'offres auprès des manufacturiers concernés, nous avons opté pour un système d'épuration dit "à sec" et qui comprend par four (figure 5): une tour de refroidissement des gaz, un réacteur dans lequel les gaz sont mis en contact avec de la chaux, des sacs filtrants ou dépoussiéreurs à manches où les gaz sont débarrassés des poussières et des particules de chaux qu'ils contiennent, y compris évidemment nos fameuses escarbilles, un ventilateur de tirage et une cheminée. Grâce au préchauffage des sacs filtrants, ce système est opérationnel même en période de démarrage alors qu'il suppléera à l'électrofiltre alors inactif.

Où en sommes-nous au moment présent?

1- Trois (3) fours-chaudières ont été jusqu'à maintenant transformés et mis en opération. Les travaux sont en cours d'exécution sur le quatrième et sa mise en service est prévue à la mi-février 1989.

2- Les systèmes d'épuration sont en voie d'installation et la fin des travaux est prévue en septembre 1989.

ÉVALUATION DES REJETS À L'ATMOSPHÈRE EN FONCTION DES MODIFICATIONS

Les émissions de contaminants atmosphériques mesurées à diverses reprises au cours des années montrent d'importantes variations d'une série de mesure à l'autre et même d'un essai à l'autre. Le tableau 2 présente un sommaire des résultats d'essais effectués depuis 1981.

Jusqu'au programme de modernisation des fours entrepris en 1985 sur le four no. 4, les essais ont montré de fréquents dépassements des normes québécoises, qui sont de 270 mg/Nm^3 pour les émissions de matières particulaires et de 500 ppm pour l'acide chlorhydrique. Les méthodes d'échantillonnage normalisées ne montrent cependant pas l'importance des particules imbrûlées (escarbilles) émises à l'atmosphère et qui ont fait l'objet de nuisances répétées au voisinage de l'incinérateur. De plus, les normes provinciales ont jusqu'ici négligé l'importance des substances organiques toxiques comme les dioxines et les furanes de même que les substances minérales dégagées par les incinérateurs à déchets municipaux.

Les modifications apportées au four no. 4 en 1985 dans le cadre du programme PEENI et décrites précédemment ont donné suite à une série d'essais complets réalisés en 1986. Les principales conclusions contenues dans le rapport de cette étude sont les suivantes:

1- Le four modifié montre une réduction substantielle des taux d'émissions de matières particulaires (tableau 2).

2- Les émissions de dioxines et de furannes mesurées dans le cadre de ce programme durant les bonnes conditions d'opération sont parmi les plus basses valeurs rapportées dans la littérature pour un incinérateur de ce type.

3- Les modifications ont permis une réduction substantielle des émissions de dioxines et de furannes (voir tableau 3).

4- Les émissions de dioxines et de furannes ont été supérieures durant les mauvaises conditions d'opération indiquant que la façon dont l'incinérateur est opéré peut avoir un effet significatif sur les émissions de ces contaminants.

5- Le monoxyde de carbone (CO) est un bon indicateur de l'opération de l'incinérateur et les conditions d'opération qui entrainent une concentration de CO inférieure à 50 ppm signifient également de faibles émissions d'organiques toxiques.

6- Les concentrations d'acide chlorhydrique ont varié entre 366 et 565 ppm et sont typiques pour un tel incinérateur non pourvu d'un système d'épuration pour les gaz acides.

7- Les concentrations des organiques et de la plupart des métaux sont plus élevées dans les cendres de l'électrofiltre que dans les cendres sous la chaudière et dans ces dernières elles sont plus élevées que dans les cendres de l'incinérateur.

Au cours des essais PEENI, les conditions d'opération ont été définies "bonnes" lors d'une opération stable avec faibles émissions de CO (<100 ppm) et un rapport de distribution d'air primaire/air secondaire adéquat (65:35). De plus, la température de la chambre de radiation devrait être supérieure à 950°C. Pour les essais à faible taux de production de vapeur, une température de 850°C a été considérée comme une bonne condition.

Suite aux essais PEENI, un nouveau programme d'échantillonnage a été réalisé en 1987 à des conditions de production de vapeur qui se rapprochent plus des conditions de design et des conditions normales d'opération (36,8 tonnes de vapeur/h). Ces essais ont montré des taux d'émissions de particules beaucoup plus élevés et excédant la norme québécoise de 270 mg/Nm^3 (tableau 2).

Le taux d'émissions moyen a été de 337 mg/Nm^3 pour un débit de vapeur moyen de 35,1 t/h. Ces fortes émissions étaient principalement attribuables à l'efficacité réduite de l'électrofiltre pour des débits de gaz élevés.

Les correctifs supplémentaires apportés au four no. 4 en 1987 et décrits précédemment ont donné suite à un nouveau programme d'échantillonnage réalisé en 1988 à des conditions d'opération correspondants à la capacité de design, soit 36,8 tonnes de vapeur/h. Le sommaire des résultats est présenté au tableau 2. On note que même à un taux de vapeur élevé, le débit des gaz de combustion est demeuré au plus bas déjà mesuré et le taux d'émission de matières particulaires a varié de 40 à 86 mg/Nm^3 représentant sa meilleure performance mesurée jusqu'à maintenant.

Les dernières modifications apportées aux fours soient principalement la nouvelle conception des tuyères d'injection d'air secondaire et la prolongation des parois refroidies à l'eau jusqu'au niveau de la grille principale et les derniers résultats d'échantillonnage permettent de conclure ce qui suit:

1- Le refroidissement des parois a éliminé les accrochages et par conséquent permet une meilleure diffusion de l'air primaire et ce, de manière prolongée et stable.

2- De plus, l'utilisation des tuyères multiples sans crainte d'accrochages permet à l'air secondaire de mieux jouer son rôle, c'est-à-dire d'assurer une bonne diffusion et un bon mélange.

3- Une conséquence directe de ces deux premières constatations est la réduction de l'excès d'air tout en assurant une meilleure combustion. La réduction des débits de gaz de combustion permet à l'électrofiltre d'opérer dans ses limites de capacité et d'être plus efficace. Une meilleure efficacité assure donc une réduction considérable du taux d'émission de particules.

4- Le refroidissement des parois latérales, la présence des dièdres et le système modifié de martelage des tubes permettent d'augmenter le rendement thermique de la chaudière en plus de réduire l'excès d'air. Les arrêts pour entretien sont moins fréquents et mineurs pour la plupart.

5- Même si la quantité d'escarbilles est nettement réduite, elles ne sont pas complètement éliminées. En effet, les particules de carbone sont les plus difficiles à capter par un électrofiltre, ceci est en effet constaté par un taux élevé de carbone organique dans les particules émises à l'atmosphère.

6- Les modifications réalisées aux fours 2, 3 et 4, et en voie de réalisation au four 1 n'ont aucun effet sur les gaz acides et par conséquent le taux d'acide chlorhydrique émis à l'atmosphère demeure élevé et excède la norme de 500 ppm.

CRITÈRES DE CONCEPTION DES NOUVEAUX ÉPURATEURS

Les systèmes d'épuration des gaz en voie d'installation sur les quatre fours de l'incinérateur de Québec ont été conçus non pas en fonction des normes actuelles mais en fonction de normes plus rigoureuses qui pourraient être imposées dans le futur. Les critères de conception des nouveaux épurateurs ont en effet été fixés à 50 mg/Nm^3 pour les matières particulaires et à 110 ppm pour l'acide chlorhydrique. Une concentration inférieure d'acide chlorhydrique pourrait être facilement atteinte.

CONCLUSION

Les essais PEENI ont confirmé les études réalisées jusqu'à maintenant sur des incinérateurs semblables, à savoir que le taux de CO est un bon indicateur de l'opération de l'incinérateur et qu'une concentration inférieure à 50 ppm signifie de faibles émissions de composés organiques toxiques. L'installation de tels moniteurs de CO est en cours sur chaque four à l'incinérateur et permettront un meilleur suivi du rendement de combustion.

Les critères de fonctionnement établis à partir des résultats des essais PEENI et de l'expérience acquise depuis, de même que l'ajout des nouveaux épurateurs assureront un contrôle plus fiable des contaminants.

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FIGURE I : CARACTÉRISTIQUES TECHNIQUES DES INSTALLATIONS.

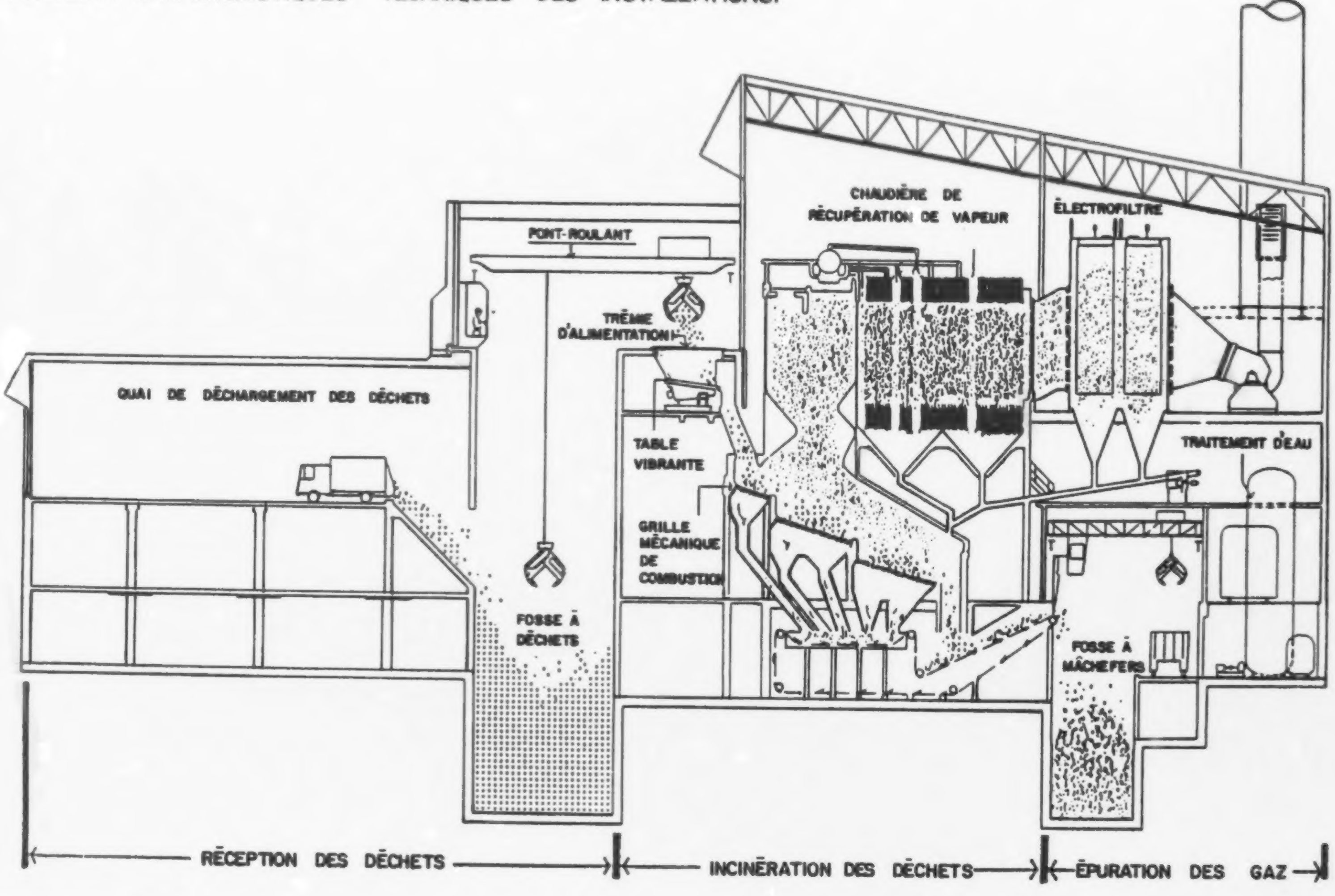
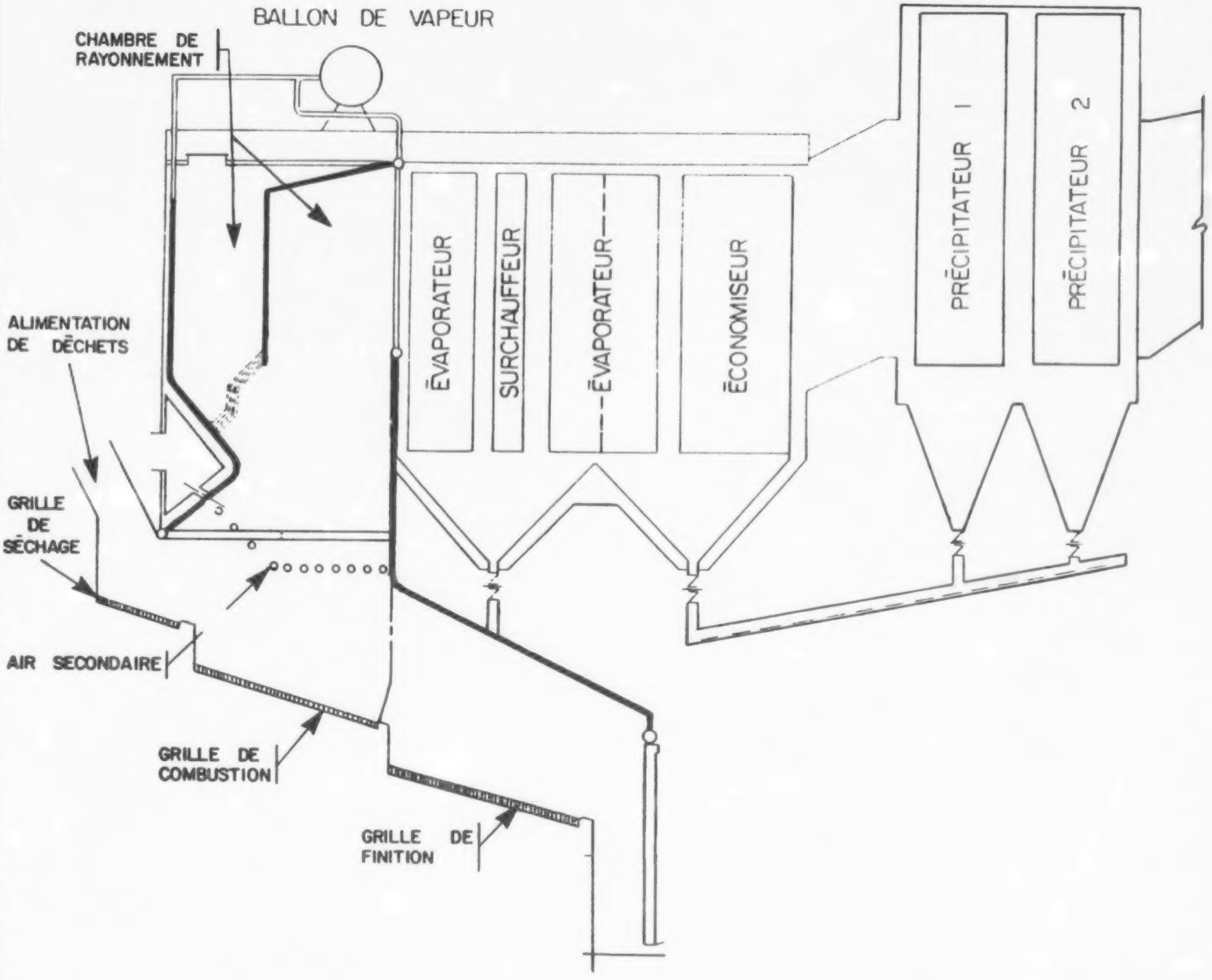

CHAUDIÈRE DE RÉCUPÉRATION DE VAPEUR
ÉLECTROFILTRE
PONT-ROULANT
TRÉMIE D'ALIMENTATION
QUAI DE DÉCHARGEMENT DES DÉCHETS
TABLE VIBRANTE
TRAITEMENT D'EAU
GRILLE MÉCANIQUE DE COMBUSTION
FOSSE À DÉCHETS
FOSSE À MÂCHEFERS
RÉCEPTION DES DÉCHETS
INCINÉRATION DES DÉCHETS
ÉPURATION DES GAZ

FIGURE 2: CONCEPTION ORIGINALE D'UN FOUR CHAUDIÈRE.


BALLON DE VAPEUR
CHAMBRE DE RAYONNEMENT
ALIMENTATION DE DÉCHETS
GRILLE DE SÉCHAGE
AIR SECONDAIRE
GRILLE DE COMBUSTION
GRILLE DE FINITION
ÉVAPORATEUR
SURCHAUFFEUR
ÉVAPORATEUR
ÉCONOMISEUR
PRÉCIPITATEUR 1
PRÉCIPITATEUR 2

Communauté urbaine de Québec
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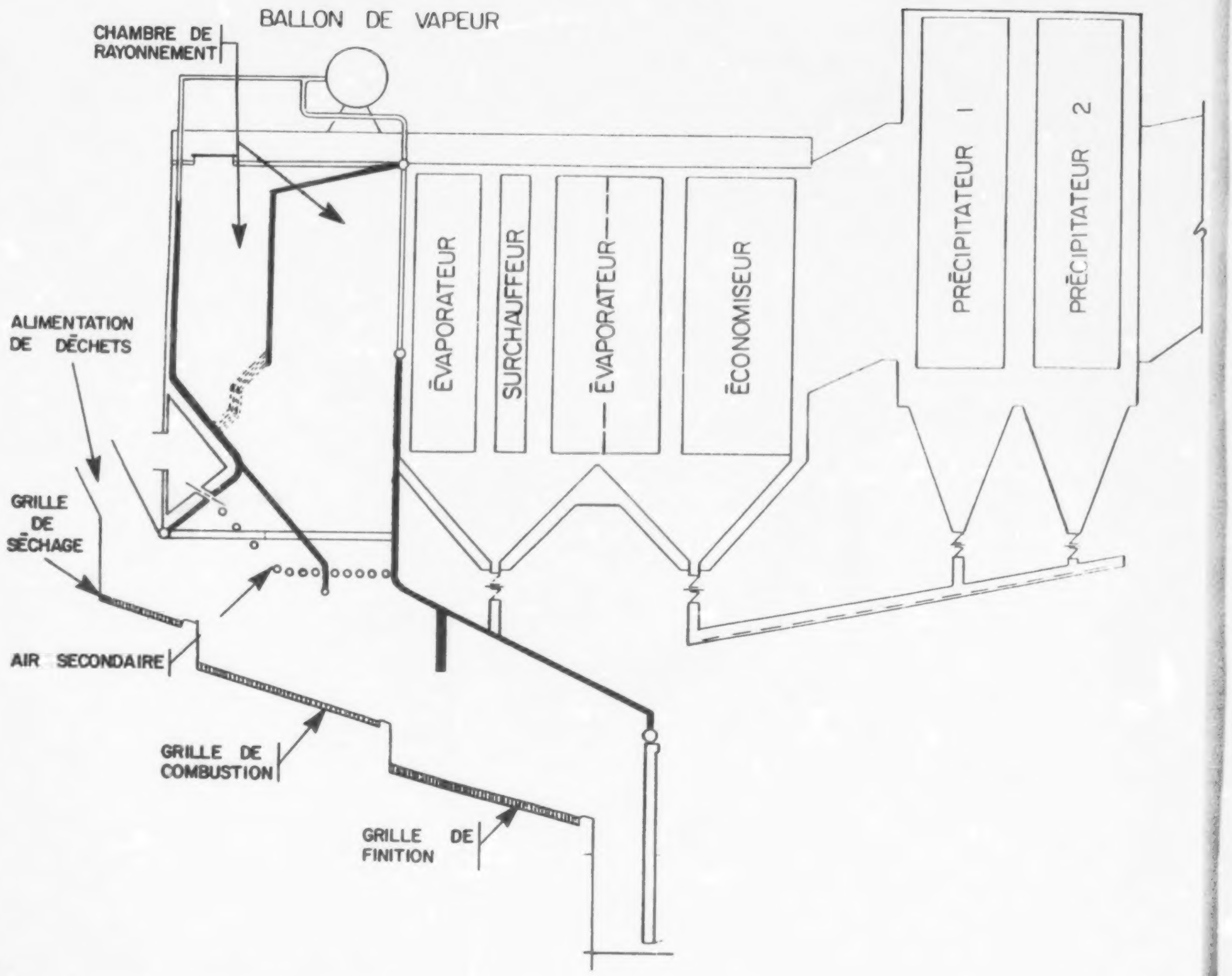
FIGURE 3: MODIFICATIONS 1978-1979.


BALLON DE VAPEUR
CHAMBRE DE RAYONNEMENT
ALIMENTATION DE DÉCHETS
GRILLE DE SÉCHAGE
AIR SECONDAIRE
GRILLE DE COMBUSTION
GRILLE DE FINITION
ÉVAPORATEUR
SURCHAUFFEUR
ÉVAPORATEUR
ÉCONOMISEUR
PRÉCIPITATEUR 1
PRÉCIPITATEUR 2

Communauté urbaine de Québec
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FIGURE 4: MODIFICATIONS 1985-1988.

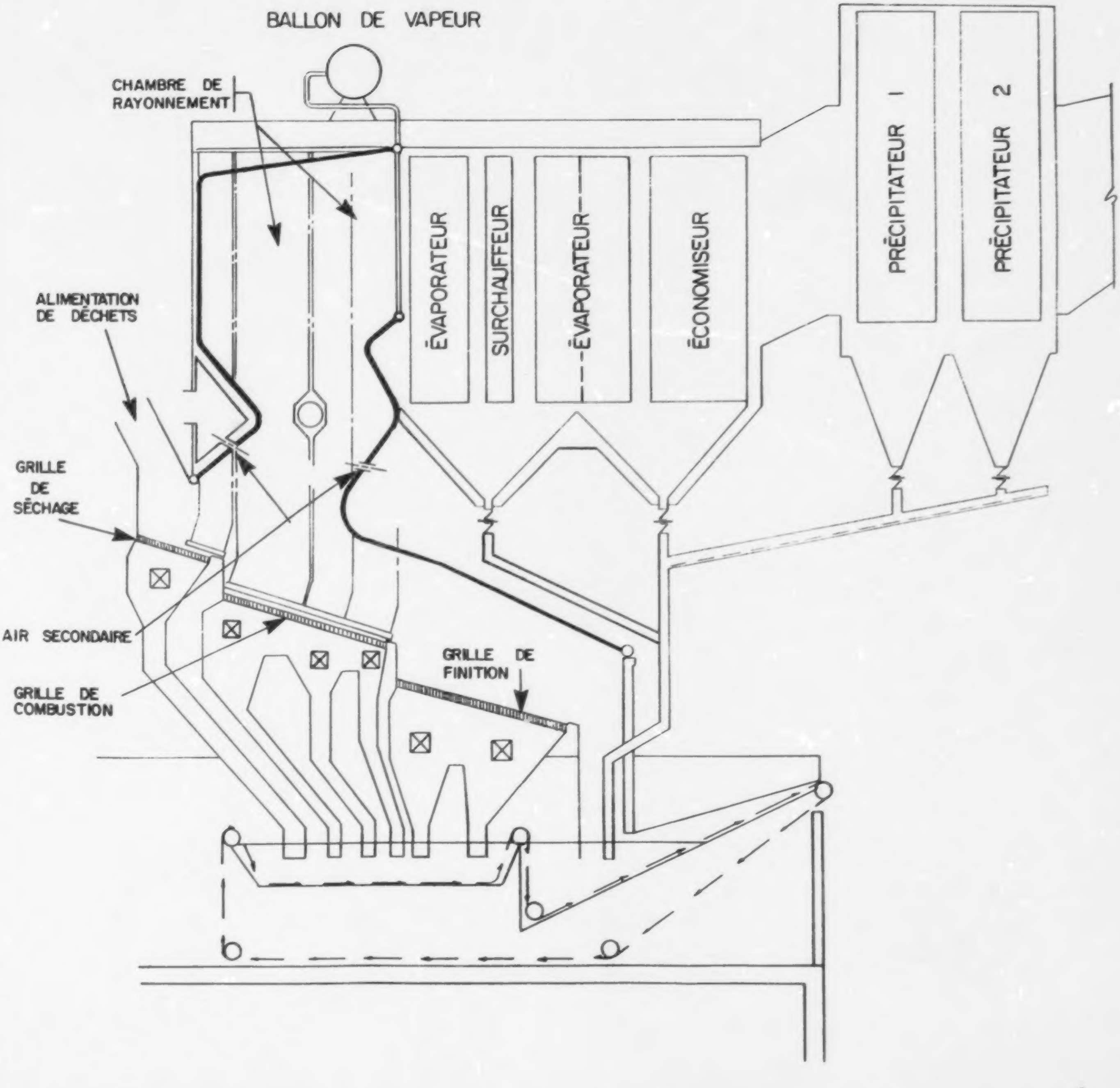
BALLON DE VAPEUR
CHAMBRE DE RAYONNEMENT
ALIMENTATION DE DÉCHETS
GRILLE DE SÉCHAGE
AIR SECONDAIRE
GRILLE DE COMBUSTION
GRILLE DE FINITION
ÉVAPORATEUR
SURCHAUFFEUR
ÉVAPORATEUR
ÉCONOMISEUR
PRÉCIPITATEUR 1
PRÉCIPITATEUR 2

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FIGURE 5: NOUVEAU SYSTÈME D'ÉPURATION DES GAZ: 1989.

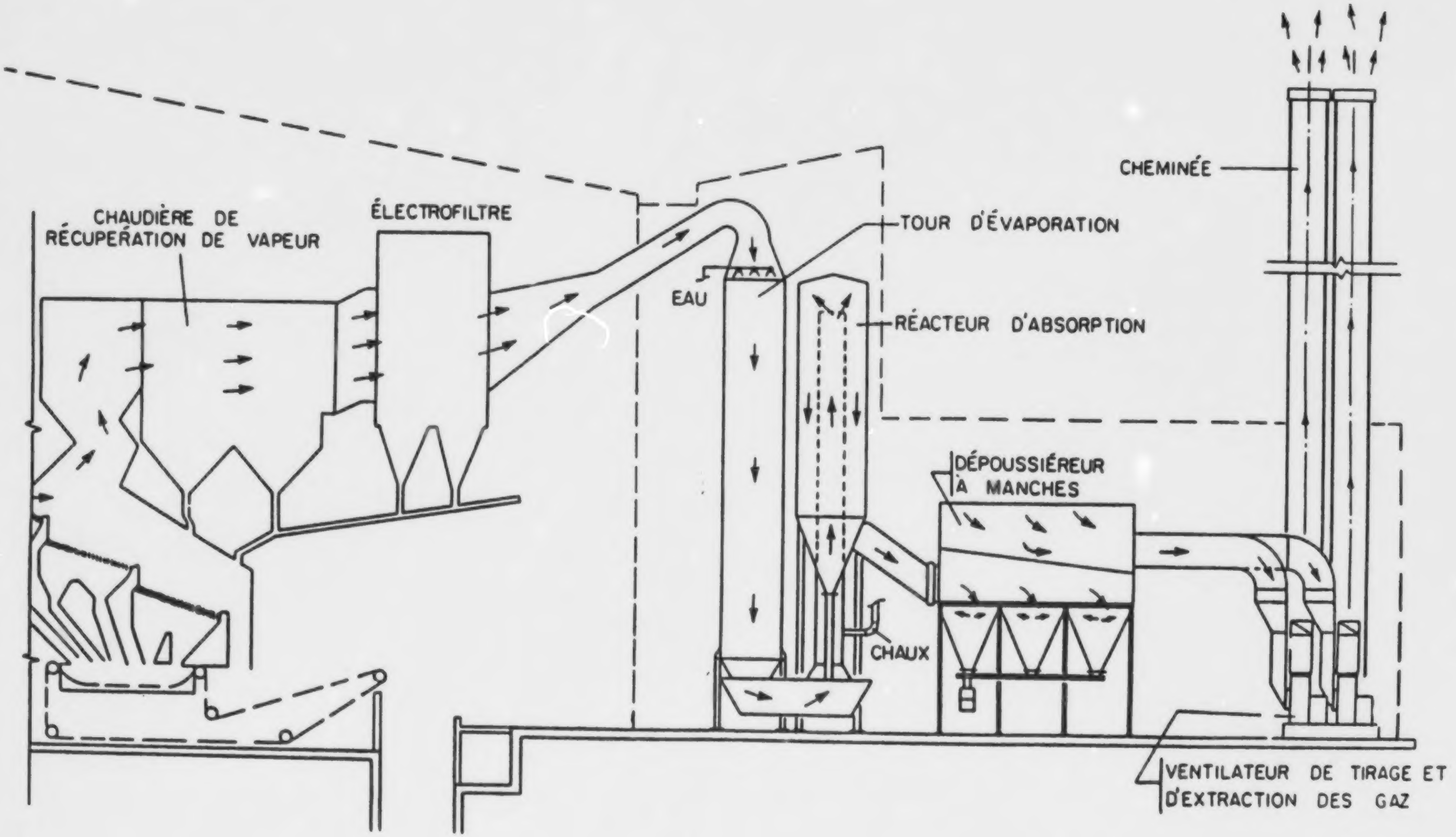
CHAUDIÈRE DE RÉCUPÉRATION DE VAPEUR
ÉLECTROFILTRE
EAU
TOUR D'ÉVAPORATION
RÉACTEUR D'ABSORPTION
CHEMINÉE
DÉPOUSSIÉREUR À MANCHES
CHAUX
VENTILATEUR DE TIRAGE ET D'EXTRACTION DES GAZ

TABLEAU 2

INCINÉRATEUR DE QUÉBEC

SOMMAIRE DES RÉSULTATS D'ÉCHANTILLONNAGE À LA SOURCE

DATE	EXÉCUTANT	NOMBRE DE FOURS	DÉBIT ACTUEL MOYEN DE GAZ PAR FOUR (m^3/h)	CO_2 (%)	TAUX DE PRODUCTION DE VAPEUR MOYEN (t/h)	ÉMISSIONS DE PARTICULES (mg/Nm^3) (1)	ÉMISSIONS DE HCl (ppm) (1)
1981	Éco-Recherche	3	186 000	3,8 à 7,8	--	247 à 456	
1982	Environnement Québec	2	142 000	4,5 à 8,1	32,0	153 à 185	503 à 881
1984	Roche Ltée	2	138 000	6,4 à 9,0	32,9	57 à 196	
1986	Roche/Lavalin	1 four non modifié	168 000	6,3 à 7,4	29,8	875 à 1470	
1986	PEENI (2)	1 four modifié	111 000	9 à 11	28,0	16 à 31	366 à 504
	PEENI (3)	1 four modifié	129 000	10 à 11	31,7	35 à 54	364 à 449
1987	Roche/Lavalin (4)	1 four modifié	151 000	7,4 à 7,8	35,1	193 à 430	
1988	Roche/Lavalin (4)	1 four modifié	107 000	10,7 à 11,5	36,8	40,5 à 86,2	489 à 592

(1) Corrigé à 12% CO_2
(2) Bonnes conditions d'opération, essais nos. 5, 6 et 12
(3) Bonnes conditions d'opération, essais nos. 7, 9 et 13
(4) Essais avec production de vapeur supérieure à 34 t/h

Communauté urbaine de Québec
Incinérateur Régional

TABLEAU 3

INCINÉRATEUR DE QUÉBEC

RÉSULTATS D'ÉCHANTILLONNAGE DES ORGANIQUES TOXIQUES

DATE	EXÉCUTANT	DIOXINES Conc. en mg/Nm³ (1) Variation	DIOXINES Conc. en mg/Nm³ (1) Moyenne	FURANNES Conc. en mg/Nm³ (1) Variation	FURANNES Conc. en mg/Nm³ (1) Moyenne
1985	Environnement Québec	836 à 3977	1985	164 à 1039	476
1986	PEENI (2)	11 à 33	19	32 à 52	44
	PEENI (3)	45 à 164	55	101 à 118	100

(1) Corrigé à 12% CO_2

(2) Bonnes conditions d'opération, essais 5, 6 et 12

(3) Bonnes conditions d'opération, essais 7, 9 et 13

FLAKT EXPERIENCE WITH AIR POLLUTION CONTROL SYSTEMS

Grant B. Frame
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ABSTRACT

The incineration of hazardous, pathological and municipal waste with energy recovery is being more and more accepted in North America. Environmental concerns of uncontrolled emissions of acid gases, organics and chlorinated dioxins have been addressed by specific testing and evaluation programs worldwide.

With over 150 gas cleaning trains at 90 MSW and hazardous waste plants consisting of dry or wet/dry reactors followed by a fabric filter or electrostatic precipitator and wet scrubbers at some locations, Flakt is the recognized leader in the application of adsorption and absorption technology to control acid gas, particulate and organic emissions from the combustion of wastes. The unique Flakt designs achieve the high removal efficiencies required by the ever-more restrictive environmental regulations in the '80's and '90's. Results of acid gas removals range up to 98% for HCl and 95% for SO_2. Organic removals for the toxic chlorinated dioxins and furans approach 99.9% plus under most fabric filter temperatures.

This paper presents a description of the Flakt experience around the world in the control of acid gases, chlorinated dioxins and heavy metals from incineration processes and gives examples of Flakt technology. Some future technology applications are also discussed.

INTRODUCTION

Major communities and regional governments throughout North America have initiated waste management studies or plans to handle substantial quantities of domestic and hazardous materials. Disposal alternatives include landfill and incineration. Advantages and disadvantages exist for both options. Incineration is becoming the logical choice for many communities faced with the lack of suitable local landfill sites and the reluctance to ship wastes the great distances required to sites outside the community. A public awareness exists, however, of the potential adverse characteristics of incineration plants and, in particular, the emission of heavy metals, chlorinated dioxins and other organics and acid gases.

A major hurdle to be overcome by the proponents of incineration is the popular misconception of uncontrollable and threatening air emissions of toxic pollutants from these plants. The Flakt Group has installed best available control technology on incineration plants located in both residential or commercial zones in major cities around the world. The uniqueness of the Flakt designs with its resultant high removal efficiencies for pollutants of concern has established the company as the leader in supplying effective control systems on MSW plants from the early 1970's to date.

This paper attempts to provide an overview of some of Flakt's incinerator air pollution control experience. Examples are described of systems currently being supplied. Furthermore, a forward look to future advancement in incineration air pollution control is provided.

BACKGROUND

Waste fired incinerators provide a very challenging application for emissions control or gas cleaning systems. The non-homogeneous nature of the feed material combined with the variability of its composition produces a wide range of gas compositions. The flue gases typically contain significant amounts of contaminants not usually present in the gases produced by firing other fuels (coal, oil, gas, etc.), such as heavy metals, chlorides, fluorides and residual hydrocarbons.

These non-typical contaminants have a significant impact on the design of gas cleaning systems, even when only particulate control is required. Historically, particulate control has been accomplished using electrostatic precipitators with or without primary mechanical collectors. Precipitator design for incinerators must incorporate: 1) lower gas velocities to protect against emission of burning particles and to enhance collection efficiency; 2) adequate corrosion protection both in materials selection and controls; 3) enhanced rapping systems to handle potentially sticky ashes and residues; and 4) state-of-the-art electrical controls to follow rapid changes in gas composition and ash characteristics. In the last twenty years, Flakt has provided over 280 precipitators for incinerators worldwide.

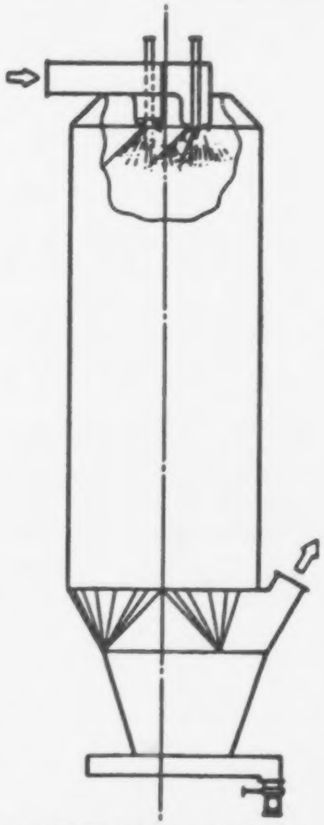
Recent regulatory changes have focused on control of acid species in incinerator flue gases, primarily hydrochloric acid and sulfur dioxide.

The systems to control emissions represent several different technologies including slurry drying, spray dryers, dry contact reactors and wet scrubbers. As was the case in utility SO_2 treatment systems, Japan was one of the first countries to impose restrictions on acid emissions from incinerators. Flakt, through its subsidiary, the Gadelius Company, has been active in supplying acid gas control systems since 1978. One of the earliest systems employed a moving ball bed reactor, designated the Nateko reactor. The reactor provides good contact between the slurry and the flue gas resulting in removal efficiencies ranging to 95% for HCl. The Nateko system has been installed in 14 incinerators in six plants, the earliest having been delivered in 1978.

A variant of the Nateko reactor, designated the Gadelius Sliding Ball (or GSB) Reactor, was developed to simplify the mechanical parts of the Nateko. The GSB was installed on eight incinerators. The improvements versus the Nateko proved to be of a limited nature and further development was cancelled.

The Nateko reactor, while very efficient, involves many mechanical parts, some of which must be precision manufactured and all of which are subject to corrosion. The resultant expenses in both capital and operating costs led to research and pilot work in several more simple reactors. Perhaps the most simple is the GAP reactor, which consists of a venturi mounted atop a modified precipitator inlet nozzle leading through standard gas distribution plates to a portion of the precipitator casing which contains only discharge wires. Hydrated lime powder is injected into the flue gas upstream of the venturi. This system has been installed on 21 incinerators without any moisture conditioning and on an additional five incinerators where a conditioning tower adds moisture to the flue gas upstream of the GAP system. The GAP system is capable of HCl removal efficiency as high as 85%, but, inasmuch as most of the plants require only a low level of control, the average operating removal efficiency for all installations is approximately 65%.

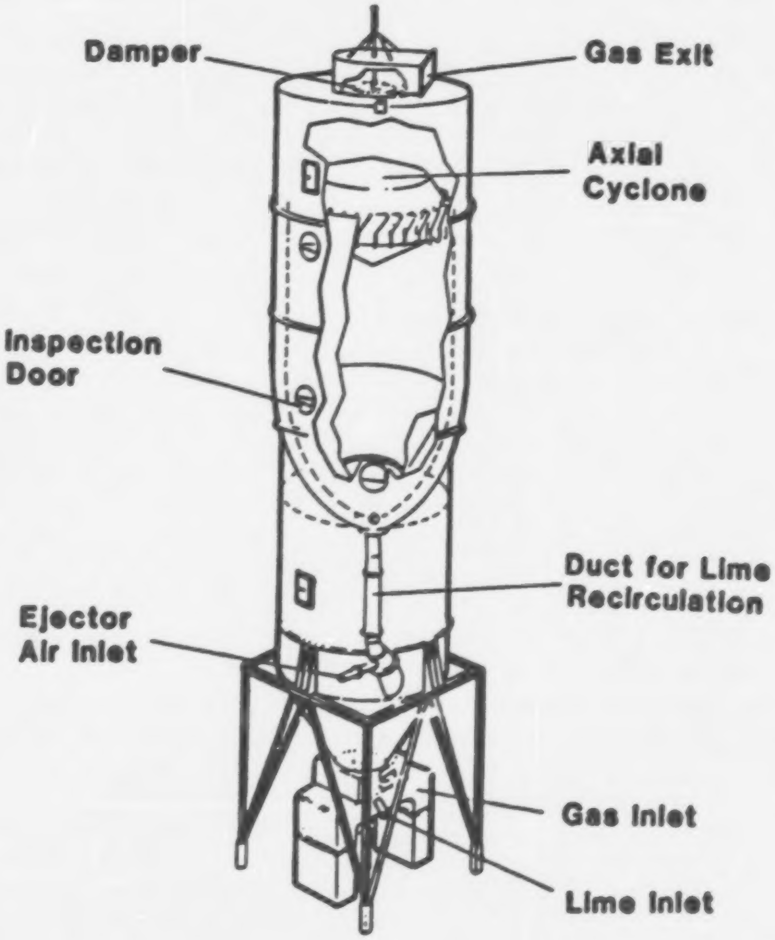
Flakt has been a supplier of cooling and conditioning towers for a long time. As an outgrowth of that technology, experiments and pilot plants were initiated in the early 1970's to develop spray drying (Figure 1) of alkaline liquids as a means of SO_2 and acid gas control. Subsequent testing at four pilot plants concentrated on SO_2 removal for coal fired boiler flue gases. The development program has culminated in orders for 15 spray dryer systems for SO_2 control on coal fired units in Europe and the U.S. These projects include both rotary and dual-fluid nozzle atomization systems. Removal efficiencies of 95% and 90% for HCl and SO_2, respectively, are typical of spray dryer systems.



DUAL FLUID NOZZLE SPRAY DRYER REACTOR

FIGURE 1

Another type of reactor developed for incinerator applications is the Dry Absorption System (DAS) reactor. This is a turbulent contacting device into which powdered hydrated lime is fed (Figure 2). The first application of this reactor was at the Sysav regional incinerator in Malmo, Sweden.


Damper
Gas Exit
Axial Cyclone
Inspection Door
Duct for Lime Recirculation
Ejector Air Inlet
Gas Inlet
Lime Inlet

FLAKT DAS REACTOR

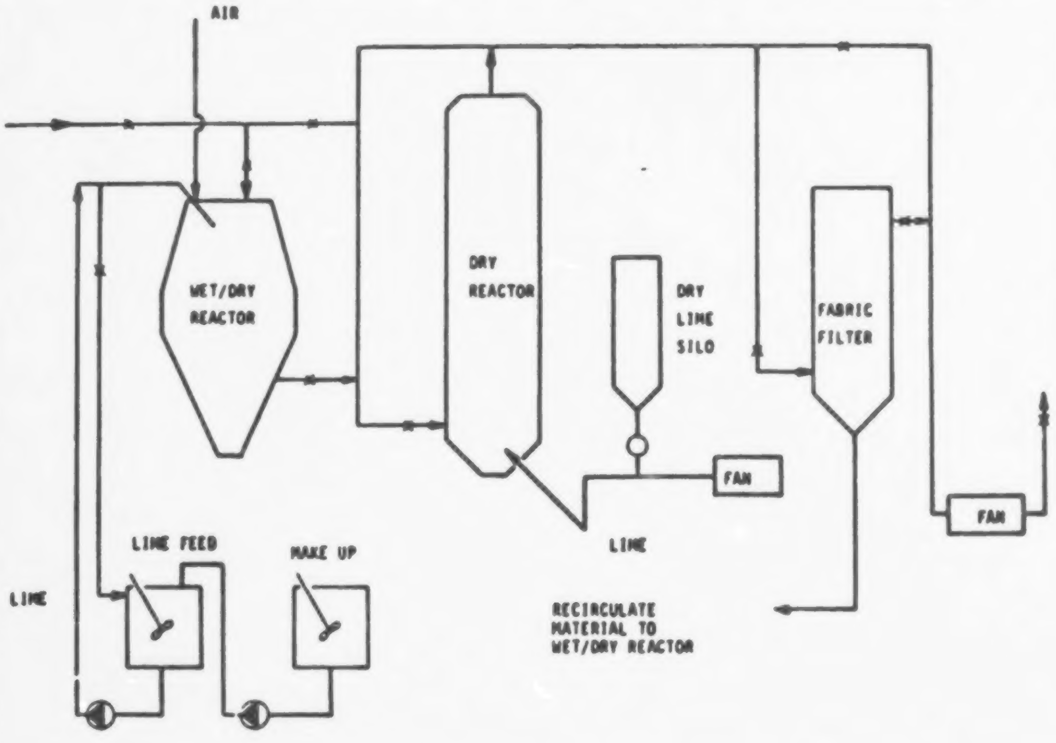
FIGURE 2

Current specifications on most incinerator plants include a requirement for SO_2 removal efficiencies of 80% or more. This requirement, coupled with the typically higher inlet loadings specified (TABLE I), has lead Flakt to propose conditioning towers and DAS reactors or spray dryers for most larger MSW incinerator plants.

TABLE I: SPECIFIED INLET CONCENTRATIONS AND TEMPERATURES

	HCl (ppm)	SO^2 (ppm)	Temperature °F
North America	1000-1500	500-800	340-450
Europe	500-1000	100-300	400-600

Flakt continues to support on-going research and development in incinerator acid gas cleaning systems. In a joint program conducted by Flakt and Environment Canada, a comprehensive series of tests were conducted on two pilot scale air pollution control systems. The tests were designed to determine the capability of these systems to control emissions of dioxins, other trace organics, metals and acid gases. Field testing was completed in August/September 1985 for two different designs: one using a wet-dry scrubber (spray dryer) plus fabric filter and the other using a dry scrubber (DAS) plus fabric filter. The systems were designed by Flakt Canada Ltd. and were erected adjacent to the mass burning incinerator in Quebec City, Canada (Figure 3).


AIR
WET/DRY REACTOR
DRY REACTOR
DRY LIME SILO
FABRIC FILTER
FAN
FAN
LIME
LIME FEED
MAKE UP
LIME
RECIRCULATE MATERIAL TO WET/DRY REACTOR

SCHEMATIC OF PILOT PLANT

FIGURE 3

Many different operating conditions were tested to identify optimum removal efficiencies for all pollutants of concern. Final results were very significant. Flue gas temperature was found to be an important operating variable for achieving high removal efficiency for many of the pollutants measured. Appropriate operating conditions were identified to obtain extremely high removal efficiencies for dioxins and furans (less than 99%), other trace organics (less than 98%), heavy metals, including arsenic and lead (less than 99.9%), and up to 97% for mercury. Excellent removal (less than 95%) was also obtained for acid gases, i.e. hydrogen chloride and sulphur dioxide.

Operating installations and pilot plant testing have provided Flakt with an extensive data base, available for supporting commercial design of acid gas cleaning plants.

The results from the numerous test reports in reference 3 to 10 are summarized in TABLE II. Various system design configurations are represented. Similar HCl and SO_2 removal efficiencies are achieved. Actual HCl and SO_2 removal appears to be dependent primarily on the degree of flue gas cooling and ratio of lime supplied to the acid gas in the inlet gas stream. Where the gas is cooled to 257°F (5), HCl and SO_2 removals of 99% and 97%, respectively, have been measured. At the higher temperatures (9, 10), higher injection rates are required for the same efficiencies. Additional SO_2 removal is noted where a fabric filter is supplied as a final collector in contrast to an electrostatic precipitator. This enhanced removal is not as obvious in the case of HCl.

TABLE II: SUMMARY OF TYPICAL PERFORMANCE RESULTS AT FLAKT EUROPEAN MSW INSTALLATIONS 1981-1987.

REFERENCE	BUSTO ARSIZIO (3)		LUGO (4)	HOGDALEN (5)		KARLSTAD (6)	SYSAV (7)	LINKOPING (8)	KEMPTEN (9)	GEISEL-BULLACH (10)
	LINE 1	LINE 2		NORMAL	LOW TEMP					
Gas Flow to APC System SCFM (Dry Gas)	19,500	17,600	12,600	53,000		21,200	2x50,500	1x24,600 1x46,000	31,600	2x20,200
Temperature, °F	1840	1750	1750	446		330	428	482	400	428
HCl, (ppmDv)	1010	1030	1360	775	600	970	820	650	1300	625
SO_2, (ppmDv)	150*	150*	140	80	135	130	120	-	95	105
O_2, % Volume	11.5	14.5	01-11	8.7		9	7	10.1	11.2	9.3
CO_2, % Volume	9.7	6.2	10.5	7-7.6		9-10	12.4	9.3	7.8	-
TSP, [gr/SCF (Dry)]	1.22*	1.22*	-	0.57	0.57	1.34	0.26	0.47	0.06	3.26*
Hg, [x10 gr/SCF (Dry)]	-	-	-	0.16	0.11	0.08	0.05	0.11	-	-
Temperature, °F at exit	471	480	482	338	253	298	347	288	401	392
HCl, (ppmDv)	47	55	32	80	3	210	26	21	110	23
SO_2, (ppmDv)	-	37	50	50	4	70	32	8	30	30
TSP, [gr/SCF (Dry)]	0.005	0.007	0.008	0.006	0.003	0.001	0.007	0.0005	0.003	0.003
Hg, [x10 gr/SCF (Dry)]	-	-	-	0.023	0.001	0.036	0.010	(0.037)	-	-
Reactor Type	Spray Dryer (DRYPAC)		DRYPAC	Conditioning Tower (CT) Dry Reactor (DAS)		CT DAS	DAS	DAS	DAS	DAS
Final Collector Type	Electrostatic Precipitator (ESP)		ESP	Fabric Filter (FF)		FF	FF	FF	FF	FF

* Design valves - not measured.

Hg valves in brackets with re injection of flyash.

The influence of gas temperature is also obvious from the Flakt demonstration plant tests in Quebec City (1). Figure 4 presents data for several tests conducted with gas cooling by water injection and evaporation with 392 to 257°F before the fabric filter. While the lime to acid gas ratio has substantial influence on removal efficiencies, the main effect at the lower temperatures is due to the cooling and the resulting humidity in the gas passing through the reactor and fabric filter.

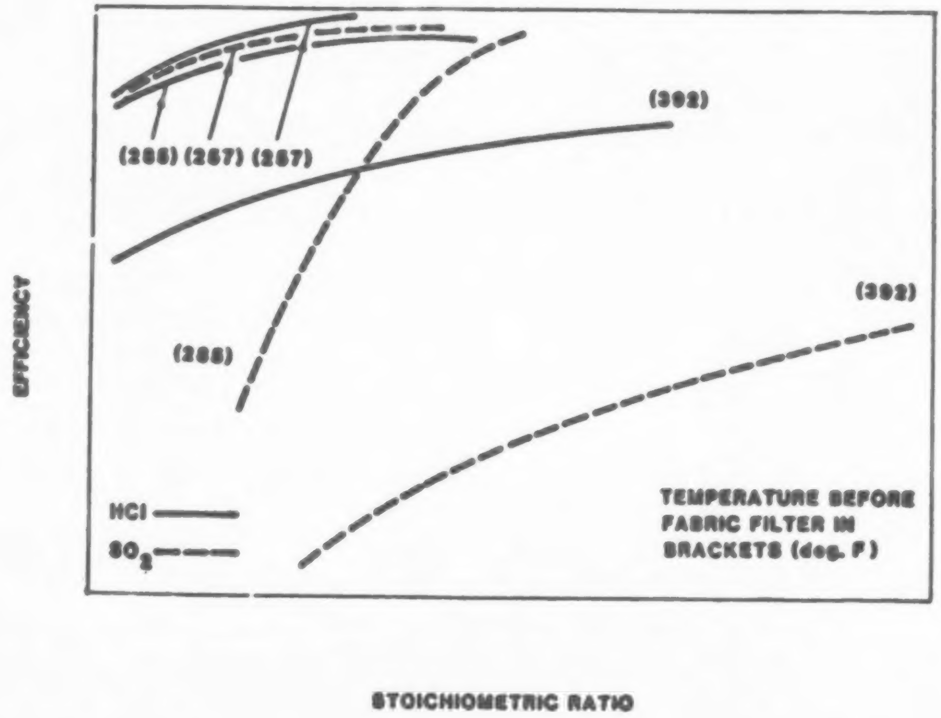


FIGURE 4

To guarantee high SO_2 removals at reasonable lime consumptions will require gas cooling to 295°F or less.

The chlorinated organics and other common hydrocarbons from the burning of municipal solid waste are collected with high efficiencies. TABLE III compares measured data from actual installations (5, 7, 8) and the comprehensive testing carried out in 1985 (1) at the demonstration plant. The actual outlet emissions of dioxins and furans from the reactor-fabric filter combination have been used to establish emission limits, elsewhere, for this class of toxic compound. At the operating temperatures recommended for high HCl and SO_2 removal, the organics including the chlorinated dioxins and furans are collected with 99% plus efficiency for all but PAH and DB. These toxic organics are removed, therefore, and are not emitted into the atmosphere. For the most part, the organics are found in the ash streams sent to the ash disposal.

Heavy metals, including mercury, have been measured from MSW plants (TABLE IV). Mercury presents unique problems as it exists in multiple forms in MSW gases. While removal efficiencies for most heavy metals are derived from total particulate removal (as they exist mainly in a solid state at the fabric filter inlet), mercury removal depends on actual gas temperatures and the presence of active sites for mercury adsorption. Existing mass burning units with unburned carbon in the flyash have shown higher mercury removals than newer, more efficient mass burning units and modular units with low flyash loadings in the gas stream. This can be compensated for with flyash reinjection in specific cases, or the use of a chemical reagent such as Na_2S.

TABLE III: HYDROCARBON EMISSIONS AND REMOVALS.

	LINKOPING (8)		HOGDALEN (5)		QUEBEC CITY (1)					
	Emissions (ng/NM^3)	% Removal	Emissions (ng/NM^3)	% Removal	Emissions (ng/NM^3)			% Removal		
2378 TCDD	0.003-0.005	98.8-99.4	-	-	230 F	284 F	392 F	230 F	284 F	392 F
T$_4$CDD	0.003-0.004	97.8-99.8	0.09	98.9	0.0	0.0	0.0	99.9+	99.9+	99.9+
P$_5$CDD	Not available		Not available		0.0	0.0	0.0	99.9+	99.9+	99.9+
H$_6$CDD	Not available		Not available		0.06	0.0	5.6	99.9+	99.9+	99.1
H$_7$CDD	Not available		Not available		0.0	0.0	5.64	99.9+	99.9+	99.4
O$_8$CDD	Not available		Not available		0.09	0.0	2.22	99.9+	99.9+	99.7
T$_4$CDF	Not available		Not available		0.0	0.0	0.1	99.9+	99.9+	99.9+
P$_5$CDF	Not available		Not available		0.0	0.0	0.1	99.9+	99.9+	99.9+
H$_6$CDF	Not available		Not available		0.0	0.0	0.1	99.9+	99.9+	99.9+
H$_7$CDF	Not available		Not available		2.3	0.97	2.42	95.4	99.4	98.6
O$_8$CDF	Not available		Not available		0.0	0.0	0.0	99.9+	99.9+	99.9+
			(ug/NM^3)		(ug/NM^3)					
PAH	-	-	0.3	-	0.1	0.11	0.015	84	84	98
CB	-	-	4.7	-	0.61	0.22	2.9	95	98	62
CP	-	-	1.0	84	0.82	0.33	8.3	97	99	56
PCB	-	-	-	-	0.009	0.0	0.009	72	99	54

Values shown as 0.0 are below detectable limit for that compound.

TABLE IV: HEAVY METALS EMISSIONS (mg/Nm^3).

	LINKOPING (8)		SYSAV (16)		QUEBEC CITY (1)	
	Emissions	% Removal	Emissions	% Removal	Emissions	% Removal
Hg	0.018*	94	.012-.024	Up to 85	0.01-0.02	95
Cd	0.002	More than 99.5	0.0001	99.98	0.0004	More than 99.9
Zn	0.3	More than 99.5	0.09	99.8	0.002-0.007	More than 99.9
Pb	0.06	More than 99.5	0.012	99.9	0.005	More than 99.9
APC System	Reactor - FF		Reactor - FF		Reactor - FF	

* With re-injection of flyash.

Examples of MSW Incinerator Advanced Gas Cleaning System in North America

In addressing the requirements imposed by North America regulatory agencies, Flakt has drawn upon its broad experience and know-how. In North America, BACT requirements have focused on technologies which can achieve significant reductions in acid gases (SO_2, HCl, HF), in addition to particulate removal.

Currently, Flakt has offered two types of systems which are at present in the construction/start-up phases. These are the Dry Adsorption Reactor (DAS) in combination with a fabric filter, and the Spray Dryer with fabric filter.

The DAS system is currently supplied to the Greater Vancouver Regional District, and to Vicon, Springfield. The Spray Dryer System supplied to Ogden Bristol, CT, which is currently in the commissioning phase, is one of six spray dryer systems currently being supplied in North America.

THE DRY INJECTION SYSTEM, BURNABY INCINERATION PLANT

Preconditioning of Flue Gases

The flue gas from one of three 225 tm/day Martin incinerators enters a conditioning tower where finely atomized water, without reagent, is injected through a system of two-medium nozzles. In the tower, the water evaporates and the gas temperature is simultaneously reduced.

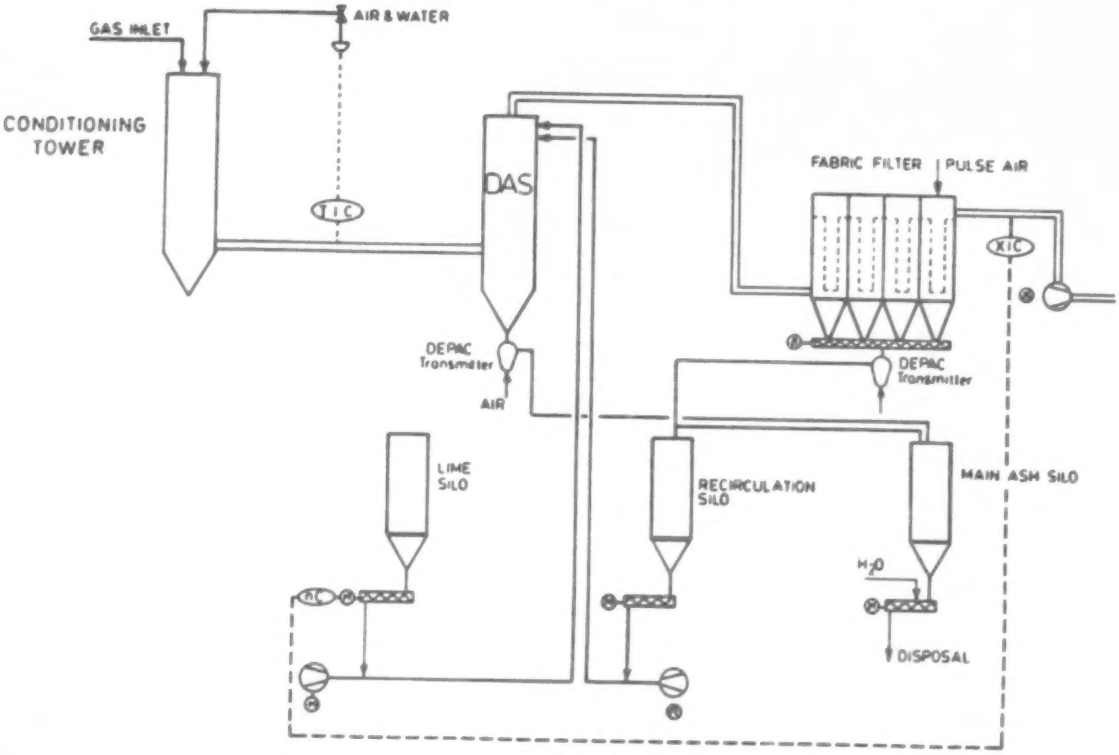
The evaporative cooling adds the following advantages to the efficiency and economy of the overall pollution control system:

- Condensation of gaseous heavy metals, mainly mercury, and organic substances such as dioxins into particulate form.
- The additional moisture enhances the subsequent removal efficiency for acid gases resulting in reduced lime consumption as compared to that without it.
- The gas volume is decreased resulting in reduced equipment size and cost.

Dry Adsorption Reactors (DAS)

From the conditioning tower, the gas is directed to a dry adsorption reactor (Figure 5) and enters through a tangential inlet in the bottom of the reactor where it is mixed with hydrated lime. The lime is pneumatically injected through an abrasion resistant nozzle.

A chemical reaction binds the acidic substances present in the gas, primarily hydrogen chloride (HCl), hydrogen fluoride (HF) and sulphur dioxide (SO_2), to the lime. The internal configuration of the reactor, designed and developed by Flakt through extensive laboratory and pilot testing, provides a lime residence time which is considerably longer than for the gas. This provides thorough mixing and an extended gas to lime contact time subsequently ensuring increased chemical reaction and excellent reagent utilization. Furthermore, the mixing and contact time will result in agglomeration of submicron particles such as condensed heavy metals and dioxins to a size range which can be efficiently captured in the fabric filter. The gas, now carrying dry reaction products, flyash and agglomerates, exits the reactor and is directed to the fabric filter for collection of the particulate.


GAS INLET
AIR & WATER
CONDITIONING TOWER
TIC
DAS
FABRIC FILTER
PULSE AIR
XIC
DEPAC Transmitter
AIR
DEPAC Transmitter
LIME SILO
RECIRCULATION SILO
MAIN ASH SILO
H_2O
DISPOSAL

SIMPLIFIED FLOW DIAGRAM

FIGURE 5

Hydrated Lime Feed System

A lime silo will be provided for storage of the fresh reagent, $Ca(OH)_2$, required for the process. The silo will be designed for an effective volume of 7 to 14 days consumption. A pneumatic fill line will be provided for loading of the silo by bulk transport truck. A material feeder with separate outlets will be provided for feed of lime. The metered reagent is discharged into separate pneumatic conveying lines equipped with blowers in which the material is transported to the reactors where it is injected into the gas stream.

Waste Handling System for the Air Pollution Control System

The dust collected in the hoppers under each reactor and fabric filter compartment will be discharged into a screw conveyor. Each hopper can be isolated by a manual shut off valve. The screw conveyors will be of airtight design to prevent intrusion of cold ambient air and subsequent condensation and plugging. The ash and chemical waste is transported to either the waste material or recirculation silo.

The waste material silo will be designed for an effective volume corresponding to a minimum of 48 hours storage capacity. A screw feeder will provide a controlled feed of dust to a flyash conditioner. By mixing of a controlled quantity of water and dust, the conditioner produces a material than can be transported to landfill on open trucks without loss of material. The conditioners are of the paddle type with two rotating shafts and a bank of water spray nozzles. Initiation of the unit admits the water and fly ash, and starts the drive system. Shutdown of the unit is by a delayed sequence so that there is no flooding with water or dusting due to lack of water.

Recirculation System

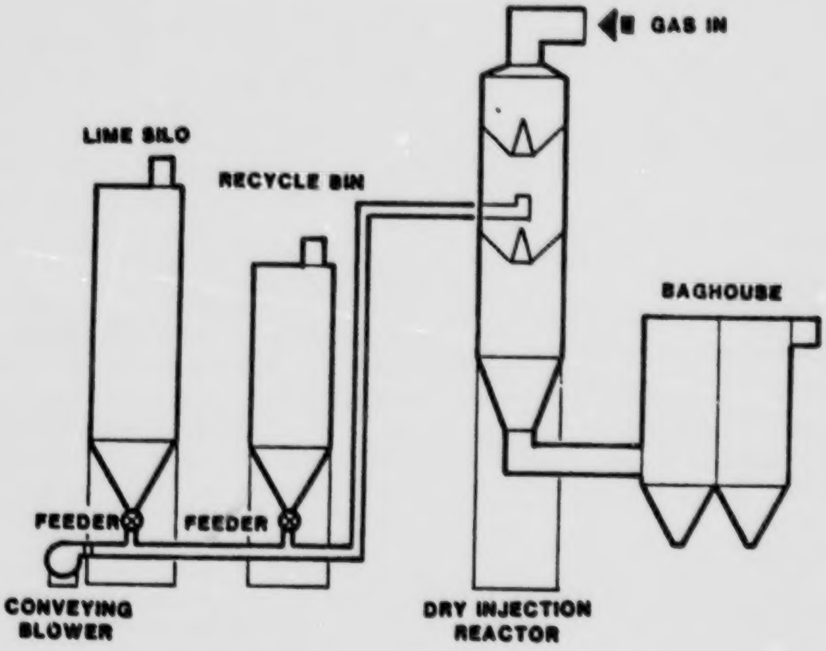
Unreacted reagent will be present in the dust collected in the fabric filters. To obtain maximum chemical utilization, a portion of the dust is recycled. The recirculation silo will be designed for an effective volume corresponding to several hours consumption. Dust will be supplied from the fabric filter and the silo feed will be controlled by high and low level sensors. The recirculated dust, like the lime adsorbent, is fed though ejectors to a pneumatic conveying line in which the material is transported to the reactor and injected into the gas stream.

SPRINGFIELD RESOURCE RECOVERY PROJECT

The Springfield Resource Recovery Project in Agawam, Massachusetts, utilizes a multistage controlled excess air mass burning technology supplied by Vicon Recovery Systems Inc. Three (3) 120 TPD units are installed, each with separate gas cleaning trains. The facility will have an electric generating capacity of 7.5 MW.

The incinerator gas from the secondary economizer is directed to a dry adsorption reactor (Figure 6) after having been cooled in the heat exchanger and enters the reactor (5'6" diameter by 17' straight side height) where it is mixed with a dry, finely powdered adsorbent, in this case, hydrated lime $Ca(OH)_2$. The absorbent is pneumatically injected through an abrasion resistant nozzle designed for a proper distribution over the reactor area.

A chemical reaction binds the acidic substances present in the gas, primarily HCL, HF and SO_2, to the lime. The special internal configuration of the reactor, designed and developed by Flakt through extensive laboratory and pilot testing, provides for optimum mixing of the gas and reagent. Thorough mixing and extended gas to adsorbent contact time subsequently ensure increased chemical reaction and excellent absorption utilization. Furthermore, the thorough mixing and the extensive contact time will result in an agglomeration of submicron particles such as condensed heavy metals and dioxins to a size range which can be efficiently captured in the fabric filter. The gas, now carrying dry reaction products, flyash and agglomerates, exists the reactor and is directed to the fabric filter for collection of the particualte.



DRY ABSORPTION SYSTEM (DAS)

FIGURE 6

A lime silo is provided for storage of the fresh adsorbent $Ca(OH)_2$ required for the process. The silo is typically designed for an effective volume of 7 to 14 days consumption. A dry material metering feeder discharges absorbent into pneumatic conveying lines equipped with blowers. The material is transported to the reactors where it is injected into the gas stream.

The dust collected in the hoppers under each reactor and fabric filter compartment is continuously discharged into a common screw conveyor system to waste or recycle.

Unreacted absorbent can still be present in the dust collected in the fabric filters. To obtain a maximum adsorbent utilization, a major portion of the dust would be directed to a recirculation silo from which it can be reinjected in the reactors. The recirculated dust, like the lime absorbent, is fed through ejectors to a pneumatic conveying line. This line transports the material to the reactor where it is injected into the gas stream.

The performance requirements are included in TABLE V. The project is currently in commissioning.

TABLE V: OGDEN BRISTOL / VICON SPRINGFIELD DATA

	SPRINGFIELD		BRISTOL	
Inlet Conditions:				
Gas Flow (ACFM)/Train	24,100		77,032	
Reactor (number/size)	3/5'6" x 17'0" H (SS)		2/23'0"x42'0" H (SS)	
Baghouse (number/size)	3/8 Hp-126-14		2/4 Hp-266-14	
Outlet Guarantees:	Mass	% Removal	ppmv	% Removal
SO_2	5.6 lb/hr	65	100	
HCl	3.2 lb/hr	90	50	90
HF	0.05 lb/hr	90	-	-
Particulate (gr/DSCF at 12% CO_2	0.02		0.01	
Opacity (%)	less than 10		less than 10	
Type of System	Dry / Dry		Wet / Dry	

BRISTOL SOLID WASTE RESOURCE RECOVERY FACILITY

The Bristol Solid Waste Resource Recovery Facility will provide solid waste disposal services to multiple independent communties. Located on a 19-acre site adjacent to Bristol's landfill, the facility will receive and process 650 tons of water per day (TPD) from the Connecticut communities of: Bristol, Berlin, Burlington, New Britain, Plainville, Plymouth, Southington, Washington, and Wolcott. Each community is guaranteeing a minimum total delivery of 153,000 tons per year to the facility.

Approximately 13 megawatts (MW) of electricity, generated by the waste-burning process, will be sold to Connecticut Light & Power Company for distribution over its system. Completed in 1988, the facility serves approximately 270,000 people who reside within the area.

Odgen Martin will own, operate and maintain the plant over a 25-year period. Commercial operation is schedules for early 1988.

The two mass burning incinerators utilize furnaces with water wall boilers, each capable of processing 325 TPD waste. The stoker grate is a Martin GmbH, inclined, reverse-reciprocating type (Figure 7).

The gas leaves the incinerator and boiler economizer and enters the top of the spray dryer reactor. At the top of the reactor, the gas is equally distributed to three inlet dispersers. The gas velocity accelerates as it passes through the dispersers. At the discharge of the disperser, where a finely atomized spray of lime slurry is introduced, the gas velocity is abruptly reduced. This causes a very high degree of turbulence which serves to assure the droplets become intimately mixed with the gas.

As the gas exits the disperser outlets and travels through the reactor chamber, which is 23 ft diameter and 42 ft high, the acid gas reacts with the calcium hydroxide contained in the droplets to form reaction products. At the same time, the sensible heat of the gas causes the water in the spray droplets to evaporate, thereby leaving a dry particulate residue suspended in the gas stream. Some of the dry reaction products and some of the ash fall out of the gas stream and are discharged through the reactor bottom (20-30% of the total).

The method of atomization used in the spray dryer/reactors is dual-fluid nozzle atomization. The reactor feed process slurry is mixed with compressed air in the Flakt dual-fluid nozzle. This two-phase fluid is then allowed to expand isentropically through the converging nozzle. Isentropic expansion occurs because the outlet pressure is below the critical pressure of the system. The enthalphy in the compressed air (125 psig) is efficiently converted into kinetic energy or high velocity. The high velocity stream of liquid is broken into small droplets due to the drag caused by the surrounding gas.

The absorption of acid gases is enhanced because the small droplets (50 to 90 microns), which are intimately mixed into the gas stream, have a large total surface area. This large interfacial area promotes the absorption of sulphur dioxide and hydrogen chloride into the aqueous phase. The acids then react with the calcium hydroxide to form the calcium/sulphite and sulphate reaction products.

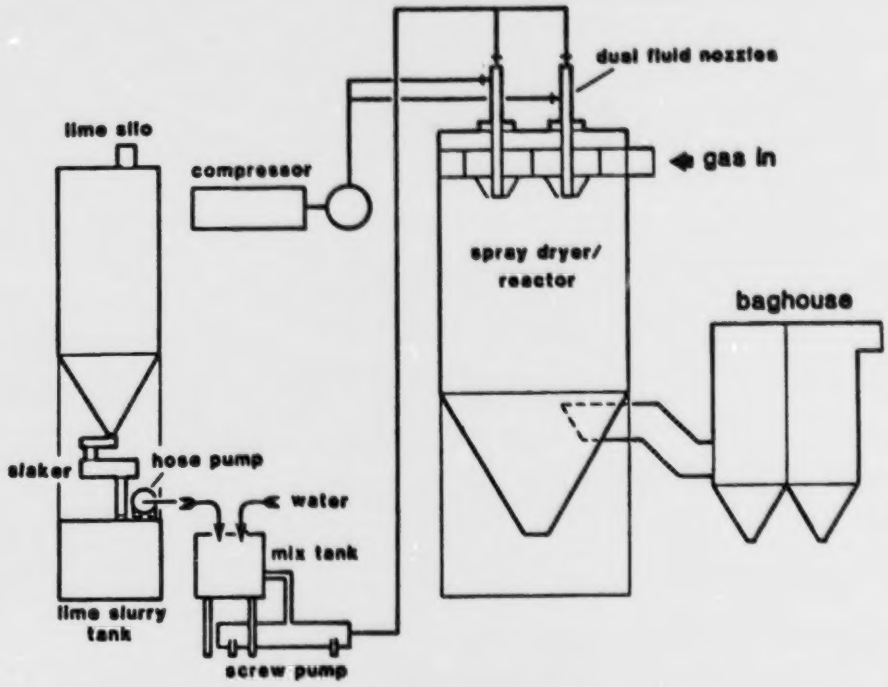
Care must be taken in the design to insure the droplet dries neither too fast, which can hinder and curtail the absorption reactions, nor too slow, which can cause a "wet bottom". The water addition rate is controlled by maintaining the flue gas temperature at the spray dryer/reactor outlet.

Flakt has successfully used, and offers, both rotary and dual-fluid nozzle atomization. For incinerator applications, dual-fluid nozzles are preferred for several reasons:

- In most applications, the total gas flow and reactor size is small enough that only one rotary atomizer could be installed. Flakt normally uses multiple nozzle assemblies. This provides the capability to perform routine maintenance for the atomizing system while remaining "on-line".

- The dual-fluid nozzle system requires no precision high speed equipment. The mechanical equipment associated with the nozzle system is easily maintained without special training or tools.
- The gas inlet for the nozzle reactor consists of a simple converging nozzle rather than the spin vanes required by rotary atomizers. This arrangement is unlikely to plug if the ash is sticky or oily.

Perhaps the greatest advantage of the dual-fluid nozzle reactor arises from the flow pattern of gases within the vessel. As shown in Figure 8, the gas and atomized slurry enter the top of the reactor in free jets. These jets dissipate and merge into essentially plug flow near the bottom of the reactor, but a strongly organized upflow of cool dry gas particulate entrained is present around the jets, along the reactor walls in the critical upper portion of the vessel. This upflow serves to isolate the slurry and incoming gas from the walls during the time the slurry and incoming gas are mixing. Since the primary reaction product in incinerator applications, calcium chloride, is strongly deliquescent, this isolation effect is a valuable feature in preventing wall deposits.


dual fluid nozzles
lime silo
compressor
gas in
spray dryer/
reactor
baghouse
slaker
hose pump
water
mix tank
lime slurry
tank
screw pump

Dual Fluid Nozzle System

FIGURE 7

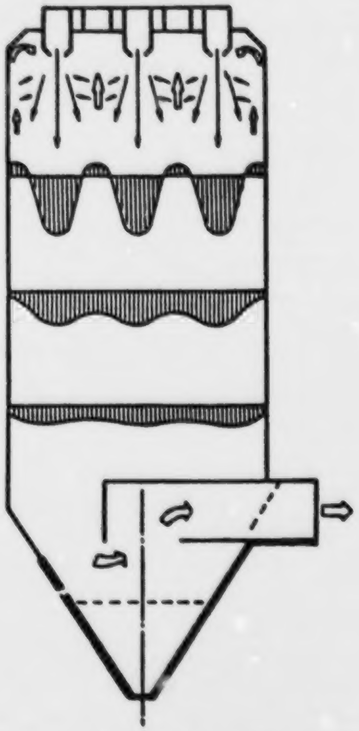
The fabric filter is a high ratio type with four compartments. This provides compartment isolation for off-line cleaning and service. The bag material is fiberglass.

Quicklime from a silo is fed to a lime slaker (1 operating, 1 spare) to produce a 20% slurry. The latter is stored after degritting in an agitated tank housed in the silo structure. Metering pumps are located near the storage tank to feed the reactor feed tanks.

The flow of concentrated lime slurry to the individual reactor feed tanks is controlled by the variation from set point of the SO_2 concentration in the gas stream from the fabric filter. The reactor feed tanks are equipped with agitators to mix the lime slurry with water for dilution and variable speed positive displacement pumps to supply the reactor nozzles with diluted slurry. The reactor gas outlet temperature controls the pump speed of rotation and liquid flow.

The dust collected in the pyramidal hoppers under each fabric filter compartment is continuously discharged into a common screw conveyor.

The performance requirements are summarized in TABLE V. The system is currently in the commissioning phase. All indications are that the performance requirements will be satisfactorily met.



GAS FLOW IN NOZZLE REACTOR

FIGURE 8

Future Advancement in APC for Incinerators

CDAS Reactor.

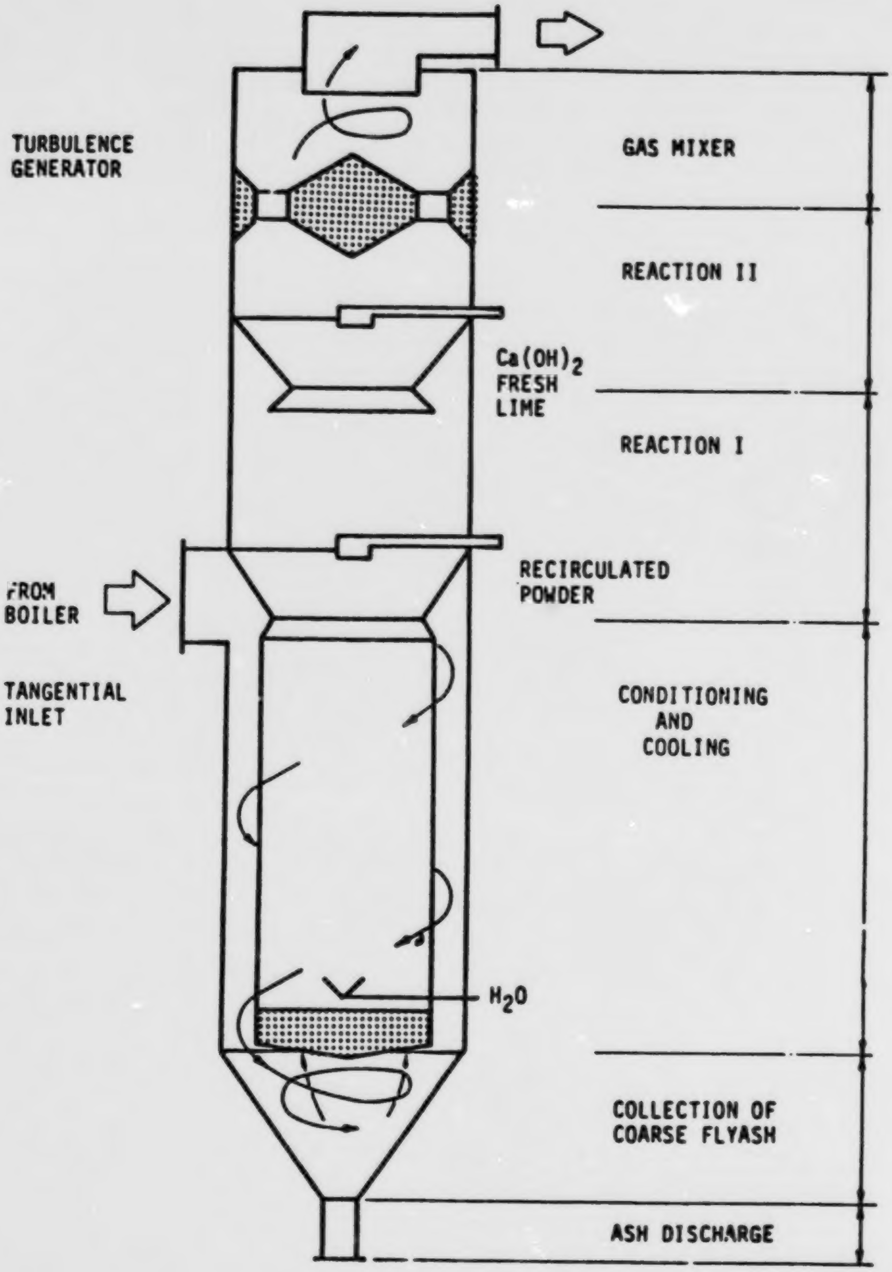
The underlying challenge in supplying air pollution control system for incinerators is to provide cost-effective and reliable systems. Systems must be capable of achieving and maintaining emissions control on a continuous basis notwithstanding fluctuation in fuel stock.

Flakt has been successful in supplying, in Europe, a variant of the spray dryer reactor and dry adsorption reactor. This "CDAS" reactor combined with a fabric filter provides the same performance as the other systems. The advantage is that water is used exclusively for cooling and reagent is handled only in the "dry" form.

The CDAS reactor has three functions in one tower (Figure 9). The tangential inlet gives a precollection of coarse boiler dust. Cooling by water evaporation takes place in the lower inner part of the tower which is heated to minimize corrosion and deposits. A vane system distributes the rotating gas from the slot into the inner cylinder, in which the atomizing nozzle is placed where the gas flow is optimal for the water evaporation of water droplets.

In the upper part, powder of fresh lime and recirculated material is injected. Special vanes and nozzles give a good mixing and contact between powder and flue gas. If the final dust collector is an electrostatic precipitator, cyclones for lime recirculation can be installed in the upper part of the tower.

The CDAS reactor is being installed with a fabric filter at several MSW plants in Europe and a hazardous waste incineration plant in Germany (start-up in 1989). The emission requirements from the latter plant are to meet or better the TA LUFT requirements.


TURBULENCE GENERATOR
GAS MIXER
REACTION II
$Ca(OH)_2$ FRESH LIME
REACTION I
RECIRCULATED POWDER
FROM BOILER
TANGENTIAL INLET
CONDITIONING AND COOLING
H_2O
COLLECTION OF COARSE FLYASH
ASH DISCHARGE

CDAS REACTOR

FIGURE 9

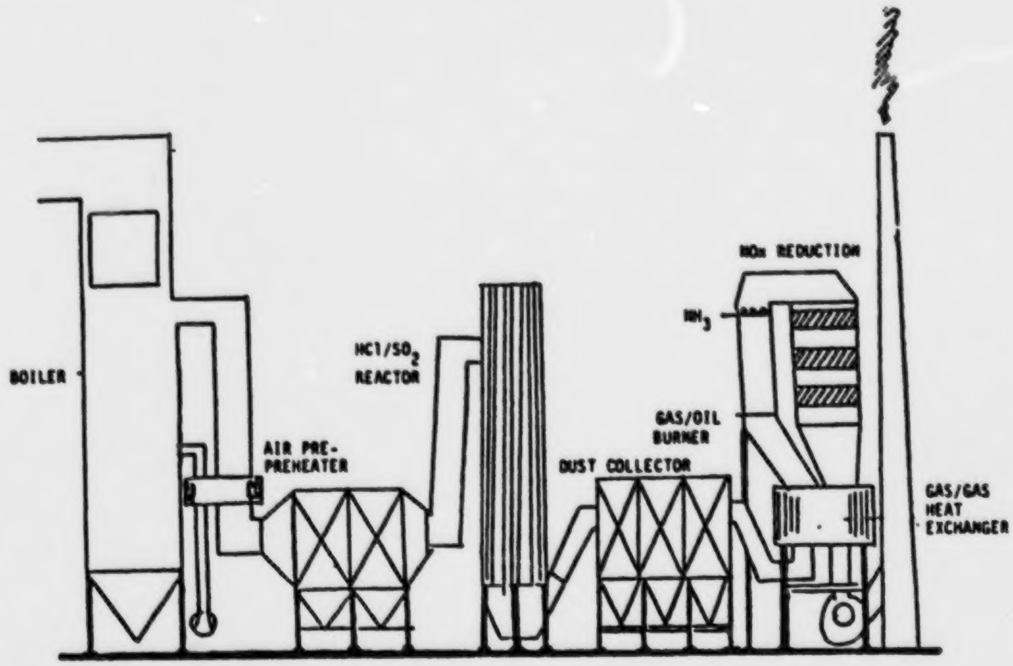
DENOx

The conventional method of reducing the NOx emission levels is through proper combustion control. Further reduction can be accomplished by non-catalytic reduction (NSCR), with ammonia, in the combustion process.

In Japan, there are commercial plants in operation where selective catalytic reduction (SCR) with ammonia is used. The catalyst is operating at about 280°C downstream of an electrostatic precipitator.

An even safer method is the tail and SCR system. The DENOx catalyst is placed downstream of the conventional acid gas control system, e.g. dry scrubber with fabric filter. Efforts worldwide are being made to identify catalysts operating at lower temperatures. Promising results have been found. Flakt is, of course, involved in this development by testing, e.g. activated coke, zeolites, etc.

Flakt is currently supplying an SCR/Acid Gas Cleaning system in West Germany (at Munich South). The plant includes two 40 MTPH (nominal 1000 MTPD) Martin incinerators each with a "CDAS" reactor and fabric filter for acid gas cleaning, followed by a tail-end SCR system. In support of this system, a one year pilot plant program will be carried out to characterize selected catalyst performance and confirm catalyst life (Figure 10).



ACID GAS CLEANING SYSTEM AT MUNICH SOUTH (FRG)

FIGURE 10

Examples of Hazardous Waste Incinerator Advanced Gas Cleaning Systems

The cleaning of gas from hazardous waste plants where, depending on the content of the feed to the incinerator, acid gas composition can exceed 10,000/2,000 mg/Nm^3 for HCl/SO_2, is more difficult than for municipal waste incinerators. Best available control technology to control:

- HCl less than 50 mg/Nm^3 dry at 10% CO_2
- SO_2 less than 100 mg/Nm^3
- HF less than 1 mg/Nm^3
- Dioxins less than 0.1 ng/Nm^3
- Mercury less than 0.03 mg/Nm^3

These are available with the previously discussed Flakt CDAS/FF and tail gas scrubbing with caustic solution. The bulk of the gas cleaning is done in the reactor and fabric filter with economical lime and the expensive caustic use is minimized in the polishing step.

The use of the fabric filter in the system guarantees low particulate emissions in the order of 10 mg/Nm^3 or less while dioxins and heavy metals are collected with high efficiencies at low system pressure drops and operating costs. In addition, depending on the operation of the final scrubber, acid gas concentrations can be reduced substantially below the previous levels given.

The removal of the heavy metals and chlorinated dioxins and furans in the fabric filter prevents their build-up in the tail gas scrubber recirculation loop and subsequent release back into the exit gas stream exceeding BACT levels for this material.

Information on a Flakt CDAS/FF installation on such a plant is given in TABLE VI following.

TABLE VI: TECHNICAL DATA ON BERLIN/SCHONEICHE HAZARDOUS WASTE PLANT

Flue Gas Flow, Nm^3/h wet	31,800
Inlet Temp., °C (max.)	280
Outlet Temp., °C	130
Inlet Moisture, % by volume	13.2 norm/15.2 max
HCl in, mg/Nm^3 dry	6912.4
SO_2 in, mg/Nm^3 dry	2304.2
HF in, mg/Nm^3 dry	288.0
Guaranteed Emissions:	
- HCl mg/Nm^3 dry	50.0
- SO_2 mg/Nm^3 dry	100.0
- HF mg/Nm^3 dry	2.0
- Class I, mg/Nm^3 dry	0.2 or less
- Class II, mg/Nm^3 dry	1.0 or less
- Class III, mg/Nm^3 dry	2.0 or less

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SOME OBSERVATIONS ON PLANNING THE DEVELOPMENT OF A HAZARDOUS WASTE MANAGEMENT SYSTEM

R. J. COOKE
President and C.E.O.
Manitoba Hazardous Waste Management Corporation

1.0 INTRODUCTION

It is a honor to be asked to talk to you today, a distinction that probably has more to do with the fact that our company is sponsoring the lunch than anything else.

In any event, it is a good opportunity for me to introduce the Manitoba Hazardous Waste Management Corporation and tell you a little about the our plans for a hazardous waste management system here in Manitoba.

I would also like to offer some observations on the general subject from the perspective of a relative new comer to the business and a province that is in the early stages of this kind of development.

2.0 PROVINCIAL HAZARDOUS WASTE PROGRAM

Manitoba initiated a long term, three phase program related to hazardous wastes in 1982. Over a five year period, the Department of Environment, Workplace Safety and Health and the provincial Clean Environment Commission conducted extensive information gathering and public information activities during the program's first phase. The results of this work were a basic regulatory infrastructure for the definition and control of these wastes, a working estimate of the provincial waste market and, perhaps most importantly, a high level of public awareness in the issue and the options available for addressing it.

Two of the major conclusions resulting from this phase were that the province required a dedicated management system and that such a system required a regulated rather than regulatory proponent. In the absence of a private sector candidate and consistent with the widely expressed public preference at public hearings, a commercial Crown corporation was formed to act in this capacity.

The start up of the Corporation in August of 1987 marked the beginning of the second phase of the overall program, at which time we set about the task of planning and ultimately building a commercial capability to manage hazardous wastes.

3.0 MANITOBA HAZARDOUS WASTE MANAGEMENT CORPORATION

The Corporation has been formed under legislation giving it the mandate to plan, develop, coordinate, own and operate a comprehensive system for this purpose. It may do so on its own or in partnership with others, essentially in the same manner as any commercial enterprise.

It's public service role is entirely non regulatory and relates to the general objectives of protection of environment and public health. In the conduct of it's business, it is required to direct its efforts to the interest of the province as a priority but not on an exclusive basis. It is obligated to be accountable for the investment being made in accordance with both financial and social tests.

As an independent agency, it reports through Board of Directors to a Minister responsible. It is financed as an equity investment of the province with a contemplated maximum borrowing authority of $35 Million. Organizationally, the Corporation is structured as a small project management team of fourteen people.

Over the past fifteen months, we have put together an overall plan for the development of a system and initiated work on it. The approach being taken is to start at the waste source and to work from this point to develop the off site system components incrementally. The building of collection, storage and preliminary treatment capability is the logical the first stage of the off site development. In the longer term, we see the potential need to have a fully integrated capability but its feasibility will require the emergence of a more mature waste market.

It is our belief that the potential for source based management should be exploited as a priority in advance of commitment to off site treatment and disposal facilities. While being consistent with a conservation ethic and serving to mitigate the common criticism that off site facilities tend to perpetuate the problem, experience elsewhere tells us that it only makes good business sense in that a significant portion of the market is going to ultimately be managed this way rather than in higher cost off site facilities.

To this end, we are operating a generator services program, modeled in large measure on the program that OWMC have developed in Ontario. In addition, we are pursuing equity investments in source based treatment ventures both in recognition that profitable opportunities exist in this area and as a vehicle to bring cooperatives of like generators together to capitalize on economies of scale.

We have also begun to offer direct waste management services in support of various public programs and to the general commercial market. An interim storage facility at Gimli has been upgraded and is now being licensed. Over the next few months, we will be putting a small transfer station in place here in Winnipeg and have initiated work with the City of Winnipeg on the feasibility of a larger scale commercial facility. I should note that we have a strong desire to pursue these developments in partnership with private interests and are actively pursuing the attraction of equity investment in them.

For the longer term, we have initiated planning for the siting and design of a central facility. We are well into the siting process, having completed a provincial screening study to identify the most desirable regions from an environmental and technical point of view. We are now beginning to work with specific communities in those regions who have expressed preliminary interest in hosting facilities.

While we have several publications available describing this work and my colleagues, Graham Latonas and Al Richards, are speaking on the subject tomorrow, I should note that we are pursuing a central facility site that is qualified to host a fully integrated facility, even though in the initial development stage a full range of treatment and disposal technologies will not necessarily be constructed. The basic approach to siting is based on finding a site meeting a set of environmental and technical criteria, as opposed to pursuing the "best" site. Having located such a site or sites, the key consideration is the acceptance of the local community and their willingness to participate directly in the detailed decision making on the siting and the facilities development.

With respect to the central facility itself, our conceptual design thinking at this point is to develop it in a minimum of two stages. The first will provide the basic infrastructure for a fully integrated site, along with the materials handling, bulking, volume reduction and analytical capability to support a brokerage facility serving a regional market. Subsequent stages will add treatment and residue disposal capability as required and economically justified. A variation or option to this basic plan that has some appeal is to provide for the periodic application of mobile technologies on an as required basis.

The schedule for this development, subject to the inevitable imponderables of site acceptance, regulatory approval and financing, is to begin detailed design and construction in early 1990, initiate first stage operation in 1991 and have a fully integrated capability as early as 1993.

4.0 OBSERVATIONS ON THE HAZARDOUS WASTE MANAGEMENT PROBLEM

To finish my talk, I would like to offer some general observations on the nature of the hazardous waste management problem as we perceive it here in Manitoba. While these will not be new to most of you, they may be worth highlighting to offer some insight into the direction we are taking.

The first observation that I would make is that there are no "quick fixes" to the hazardous waste issue. We should have realized by now that the provision of a comprehensive universal capability to manage hazardous waste on a dedicated basis is a complex, time consuming and often expensive process. It requires the collective efforts of all the stakeholders in the undertaking. This includes public policy makers, regulators, municipalities, waste managers, waste generators and the general public. Cooperation, coordination and risk sharing by all these groups over a sustained period is necessary for it to succeed.

The second observation relates specifically to the need for maturity in the cooperative efforts of various jurisdictions. A balance must to be struck between the moral obligation of all jurisdictions to provide management capability for their own wastes and the practical economic limitation that everyone will not be able to afford everything that is required. This is particularly true in our case. The logical approach for us is to be part of a regional system involving neighboring provinces and states that share capability. Clearly this will require sustained public policy commitments to deal with the public reaction to the acceptance of others wastes.

It is also useful to examine what assets that a hazardous waste management system must acquire. In terms of physical assets, the infrastructure, technology, facilities and operating expertise are obviously needed. In reality, all are readily available, either by purchase or hire. What is difficult to acquire is the locations to apply them. In effect the critical and probably the most valuable assets a system can have sites that are acceptable and accepted for development and use.

The financial capability to undertake the development is also important to consider. The question immediately arises as to where it should come from and more fundamentally how are the financial risks and liabilities distributed. In our situation and likely for any comprehensive system development, a purely privately financed system is likely difficult to structure or even to sell to the public. However, a mixed equity venture with a fair apportionment of risk and liability between the private and public sector has merit. This type of arrangement could apply to various components of the system or to the system as a whole. The potential partners in it range from municipal and provincial governments through to established waste management firms, waste generators, technology proponents and others offering financial capacity and/or expertise.

As a final observation, I would like to comment on the public's perception of the issue and how they feel it should be addressed. There is currently a high demand for action on the issue, both through regulation and the provision of solutions. While positive in the sense that it serves to accelerate action, this demand is emotionally based and focused on specific issues like PCB's rather than on the issue as a whole. The danger in this is that short term and reactive solutions will be presented that could consume the finite financial resources available, particularly in the public sector, without actually dealing with the problem in any lasting sense. This could serve to further diminish the credibility of all of us, from regulators through to waste managers.

In addition, a reactive as opposed to anticipatory approach serves to perpetuate the public's somewhat schizophrenic view of the issue. While demanding solutions and sanctions, they view the problem is someone elses responsibility and as individuals are not willing participants in the solutions. In reality, public resistance to the solutions remains the largest single constraint to providing them.

As a parting thought, I would suggest that we have a collective responsibility to keep the broader issue in perspective and integrate the public into the solutions proposed to address it. This can only be accomplished by adopting a highly consultative and open approach to our business that ultimately offers the public some meaningful say in how we conduct our business.

5.0 Conclusion

In conclusion , we are excited about the prospects of developing a hazardous waste management system here in Manitoba. This undertaking offers some interesting challenges and opportunities, the pursuit of which we look forward to working with many of you on.

I hope you have enjoyed your lunch and trust listening to me was not to high a price to pay for it.

Thank you.

L'INCENDIE D'UN ENTREPÔT DE BPC
À SAINT-BASILE-LE-GRAND, QUÉBEC

MME CLAUDETTE JOURNAULT, B.SC. ENVIRONNEMENT QUÉBEC
MME FRANCINE LAPERRIÈRE, ING., M.SC. ENVIRONNEMENT CANADA
M. RAYMOND PERRIER, M.SC. ENVIRONNEMENT QUÉBEC

INTRODUCTION

Si on avait connu en 1881 l'immense succès commercial qui attendait les BPC, on aurait sans doute attribué le prix Nobel au chimiste qui venait d'en réussir pour la première fois la synthèse. Mais c'est un demi siècle plus tard que les BPC sont introduits dans le monde industriel où ils jouissent d'une popularité phénoménale grâce à leurs exceptionnelles qualités: stabilité chimique, résistants à la combustion, grande capacité d'échange de chaleur, super isolants électriques, etc. La grande vogue des BPC aura duré quelque cinquante ans (1929-1977); cinquante ans de vie utile, paisible, discrète et en apparence inoffensive. Mais sur le plan environnemental: quel gâchis!

Non pas que les BPC soient la redoutable substance toxique que les journaux brandissent comme un épouvantail à n'importe quel moment! La tolérance de l'homme aux BPC est très élevée! Mais c'est une substance dangereuse parce que persistante dans l'environnement, peu dégradable, qui s'accumule dans les tissus gras des êtres vivants, des poissons, des mammifères, qui se transmet aux nourissons par le lait maternel et qui présente des risques de causer des mutations génétiques, des malformations congénitales, des problèmes de croissance.

Face à ces risques que la science n'a pas encore fini de cerner, les gouvernements des États-Unis et du Canada, interdisent la fabrication des BPC en 1977 puis en restreignent l'usage et l'importation.

C'est à partir de cette date qu'on voit apparaître en Amérique du Nord de petites compagnies proposant aux industries, à des coûts souvent attrayants, parfois faramineux, de les débarrasser complètement de leur BPC devenu problème. Proposition osée puisqu'aucun moyen d'élimination n'est véritablement disponible.

L'ENTREPÔT DE BPC DE SAINT-BASILE-LE-GRAND

C'est dans ce contexte que naît l'entrepôt de BPC de Saint-Basile. Présenté d'abord en août 1978 comme un centre de traitement de résidus chimiques, le projet ambitieux de monsieur Paul Allain, évolue rapidement vers l'établissement, plus modeste, d'un centre d'entreposage de BPC. Le traitement et l'élimination sont remis à plus tard.

Le 15 août 1979, un premier certificat d'autorisation est émis à la Cie SOTERC Inc. pour un tel établissement d'une capacité de 1 000 gallons. Le 10 octobre 1979, un nouveau certificat d'autorisation porte cette capacité à 5 000 gallons et le 13 mai 1980, à 20 000 gallons.

En avril 1981, la Cie SOTERC est achetée par la Cie # 1845-0858 de monsieur Marc Lévy. Une demande d'augmentation de la capacité d'entreposage jusqu'à 40 000 gallons est refusée par Environnement Québec.

En août 1988, au moment de l'incendie, l'entrepôt contient, selon les registres, quelque 22 400 gallons d'askarels dans des barils de 45 gallons. Une quantité indéterminée d'huiles isolantes et de résidus contaminés par des BPC est également entreposée dans d'autres barils, ou encore dans des condensateurs et transformateurs mis au rancart intégralement.

L'INCENDIE ET LES ACTIONS INITIALES

L'incendie éclate le mardi soir, 23 août 1988, vers 20:45 heures.

Il est bon de se rappeler que le principal danger lors d'un incendie de BPC n'est pas dans les BPC eux-mêmes mais dans les sous-produits de combustion.

La combustion des BPC peut générer des dioxines qui sont des millions de fois plus toxiques que les BPC. En présence de chlorobenzène ou d'autres organochlorés, ils produisent la dangereuse 2.3,7,8, TCDD la plus toxique des 75 dioxines (isomères et congénères). La combustion incomplète des BPC produit surtout des furannes.

C'est pourquoi, dès le début, alors que les postes de radio et de télévision diffusent en direct les diverses péripéties de la progression du feu, les environnementalistes et toxicologues pensent à mettre immédiatement à l'abri la population des environs. Ceux qui vivent en aval du foyer d'incendie dans la zone de diffusion du panache sont plus immédiatement menacés par les émanations de fumées, gaz, suies et goutelettes contaminées. Les vents soufflent du sud-est; on évacue donc en priorité les populations de St-Basile-Nord, Ste-Julie-les-Hauts-Bois et St-Bruno-Trinité. Opération délicate rapidement réalisée grâce à une collaboration remarquable des corps policiers locaux et de la Sûreté du Québec.

Environ 3 800 personnes quittent leur domicile pour une salle d'école, un gymnase ou un hôtel. Ils demeureront 18 jours à l'extérieur de leur foyer!

Les pompiers de Saint-Basile sont immédiatement alertés et prennent charge du site de l'incendie. Les services d'urgence d'Environnement Canada et d'Environnement Québec sont rapidement sur place pour porter assistance aux pompiers et pour aviser sur les mesures préventives à prendre.

Il faut rendre hommage au courage et à la tenacité des pompiers de St-Basile et des municipalités environnantes qui tentent de maîtriser l'incendie avec des équipements conventionnels (lances à incendie, canaux à eau) alors que les murs métalliques de l'entrepôt empêchent l'eau d'atteindre le foyer principal d'incendie.

La chaleur dégagée par l'incendie est trop forte pour permettre à quiconque de pratiquer une brèche importante dans le toit ou les murs de l'entrepôt. Cette brèche, elle est créée par une explosion qui ouvre le toit. Par la suite, le travail des lances à incendie et des canons à eau permet de refroidir suffisamment le brasier pour favoriser l'entrée en action des pompiers de la Défense nationale, de la base des Forces canadiennes de Saint-Hubert. Ces derniers réussissent à étouffer les flammes en utilisant 25 000 litres de mousse anti-incendie à la suite d'un travail acharné de trois (3) heures.

On se rendra compte dans les jours suivants qu'un nombre limité de barils de BPC a explosé et brûlé... moins de 10% du contenu de l'entrepôt. Grâce au travail remarquable des divers corps de pompiers, une catastrophe aux dimensions dix fois plus importantes a été évitée.

Dès les premières heures de l'incendie, le Service de l'Environnement atmosphérique du Canada fournit des des observations météorologiques spéciales, des prévisions et des simulations de la dispersion des gaz.

Une équipe spécialisée du Centre de Technologie environnementale (Environnement Canada, Ottawa) arrive sur les lieux à 5:00 heures le 24 août pour assister le ministère de l'Environnement du Québec dans l'échantillonnage de l'air, de l'eau et du sol.

Une première station d'échantillonnage d'air est installée par Environnement Canada en face du site de l'entrepôt pour mesurer la concentration de BPC, dioxines et furannes dans l'air. Une première série d'échantillons de sol et d'eau est prise au site de l'entrepôt et en face de celui-ci pour déterminer le plus rapidement possible le degré de contamination auquel les travailleurs sont exposés.

Même pendant l'incendie, Environnement Québec procède aux premières mesures de sécurité environnementale: protection des eaux de surface et des eaux souterraines, confinement des eaux d'arrosage sur le site de l'entrepôt et surveillance de la qualité de l'eau potable du Lac du Moulin.

À la demande d'Environnement Canada, l'équipe du laboratoire mobile (TAGA 3000) (Trace Atmospheric Gas Analyser) du ministère de l'Environnement de l'Ontario procède dès le 27 au dépistage des BPC dans les rues et les maisons des quartiers susceptibles de contamination.

SANTÉ

Le ministère de la Santé et des Services sociaux du Québec dispense les services de santé publique et de soins du début de l'incendie jusqu'au jeudi soir, le 25. On dispense le support d'information aux travailleurs et à la population sur les risques que présente l'événement et sur les moyens de se protéger. Le Centre de Toxicologie du Québec et les Départements de santé communautaire de St-Hyacinthe et de Charles Lemoyne et le CLSC de la Vallée des Patriotes sont mis à contribution. Ils participent aux évaluations toxicologiques de la gravité de cet accident environnemental et amènent les autorités à retarder la réintégration de la population évacuée jusqu'à ce qu'on dispose des données environnementales suffisantes pour établir hors de tout doute les conditions sécuritaires de réintégration. Ils offrent enfin de façon systématique les services d'évaluation médicale à toutes les personnes de la zone influencée par l'incendie. Environ 5 600 examens médicaux seront réalisés et un suivi médical et épidémiologique se poursuit sur près de 450 travailleurs.

AGRICULTURE

Le ministère de l'Agriculture, des Pêches et de l'Alimentation du Québec procède à l'évaluation de la contamination potentielle des aliments et du bétail sur une vaste superficie de terres potentiellement affectées. Au total, 472 échantillons de lait, de produits végétaux, de divers aliments, de sang et de sols sont recueillis et analysés. Un embargo est mis sur la commercialisation des produits de 4 700 acres de terre en raison de leur contamination potentielle. Les résultats finals des analyses permettent de relever de l'embargo une partie de ce territoire et de le restreindre à 3 500 acres.

RÔLE DES INTERVENANTS

Le poste de commandement dirigé par la Sûreté du Québec a comme mandat de: voir au maintien du périmètre évacué (14 Km^2) et à la sécurité publique, coordonner les ressources financières et matérielles avec l'aide de la Protection civile du Québec et du Canada, coordonner les interactions des différents intervenants (Ministères, Organismes gouvernementaux et Municipalités) et coordonner la diffusion de l'information à la population, aux sinistrés, à la Presse, etc.

Voici les différents ministères, organismes et municipalités impliqués dans l'intervention d'urgence à St-Basile et le rôle que chacun y a joué:

Intervenants	Rôle
1. Municipalités de St-Basile " de St-Bruno " de Ste-Julie	. Représentation des citoyens aux diverses réunions du Comité coordination où des actions prises sont discutées.
2. Protection civile du Québec	. Coordination des ressources financières et matérielles des Ministères et Organismes provinciaux impliqués. . Établissement de centres d'information à l'intention du public affecté.
3. Protection civile du Canada	. Coordination des ressources financières et matérielles des Ministères et Organismes fédéraux impliqués.
4. Ministère de la Santé et des Services sociaux du Québec	. Centre spécial de services sociaux mis sur pied pour les prochains six (6) mois.
5. Santé et Bien-Être Canada	. Support à Santé et Services sociaux du Québec.
6. Ministère de l'Agriculture du Québec	. Coordination de l'échantillonnage des terres agricoles et de l'inspection des marchés de vente des produits de la région.
7. Agriculture Canada	. Support à Agriculture Québec pour l'inspection.
8. Ministère de l'Environnement du Québec (MENVIQ)	. Caractérisation environnementale de la zone sous influence. . Coordination des travaux de prévention au site de l'incendie (confinement, décontamination, démantèlement, mesures d'atténuation).

TABLEAU (SUITE)

Intervenants	Rôle
	. Coordination de l'échantillonnage de suivi: eau, air, sol, faune, végétation. . Centre de communication aux médias. . Application des mesures environnementales préconisées par le Comité d'experts internationaux lors de la réintégration des citoyens. . Restauration complète du site de l'incendie.
9. Environnement Canada	. Support au Menviq pour la coordination de l'échantillonnage durant l'événement (compilation, distribution des échantillons vers 8 labos au Canada, analyse et contrôle de qualité des labos). . Support au MENVIQ pour les prévisions météorologiques locales (station météo installée à St-Basile) durant l'événement. . Support au MLCP par le Service canadien de la faune pour l'échantillonnage de la faune afin de déterminer l'impact de l'incident. . Support au MENVIQ pour la vulgarisation scientifique dans les centres d'hébergement. . Centre de communication aux médias.

TABLEAU (SUITE)

Intervenants	Rôle
	. Enquête en vertu de la Loi canadienne sur la protection de l'environnement (LCPE).
10. Ministère de l'Environnement de l'Ontario	. Support au MENVIQ pour la détection de BPC dans l'air ambiant avec le laboratoire mobile TAGA 3000.
11. New York State Department of Environmental Conservation	. Support au MENVIQ pour la détection de contaminants dans l'air ambiant avec le laboratoire mobile TAGA 6 000.
12. Ministère du Loisir, de la Chasse et de la Pêche du Québec (MLCP)	- Coordination de l'échantillonnage de la flore et la faune pour connaître l'impact de l'incident.
13. Ministère de la Défense nationale du Canada	. Support pour combattre l'incendie et pour acheminer efficacement les échantillons vers les laboratoires de River Road (Ottawa) et des Eaux intérieures (Burlington).
14. Communications Canada	. Support logistique pour assurer des communications adéquates entre les centres d'opération.
15. Comité d'experts internationaux 6 délégués étrangers de l'Organisation mondiale de la Santé 6 Canadiens 2 invités des U.S.A.	. Interprétations des résultats d'analyse (eau, air, sol).

Il n'est pas facile de persuader 3 800 personnes du bien fondé de leur évacuation une fois l'incendie éteint. Lorsque cette évacuation se prolonge pendant 18 jours, il devient encore plus difficile de convaincre les gens qu'il est tout à fait sécuritaire de retourner chez eux.

C'est pourquoi, un Comité d'experts internationaux est appelé à scruter toutes les données environnementales de CARACTÉRISATION disponibles et à les interpréter pour élaborer les conditions d'une réintégration sécuritaire.

LA CARACTÉRISATION ENVIRONNEMENTALE

La caractérisation environnementale a été réalisée grâce à la collaboration soutenue d'Environnement Canada. Environnement Québec a également pu compter sur la précieuse collaboration de plusieurs scientifiques de différents organismes précédemment cités qui ont travaillé dans les laboratoires répartis sur l'ensemble du territoire canadien. C'est grâce à la synergie de quelques centaines de scientifiques et techniciens qu'il a été possible d'établir le portrait de la situation environnementale dans la zone d'influence. Voici donc les points saillants de cette étude.

LE PLAN D'ÉCHANTILLONNAGE

Un plan d'échantillonnage est élaboré en fonction de la direction du panache de fumée lors de l'incendie et en tenant compte des usages du milieu. Le plan couvre cinq zones principales dont Saint-Basile-le-Grand, Domaine des Haut-Bois, Sainte-Julie, Saint-Bruno et Boucherville (Figure 1).

Des échantillons sont ainsi prélevés sur les composantes environnementales suivantes: l'air, l'eau de surface, l'eau souterraine, les frottis extérieurs et intérieurs des résidences de même que des échantillons de sol.

Étant donné la quantité importante d'échantillons générés lors de la campagne de prélèvement et la complexité des analyses (on sait par exemple qu'une analyse de dioxine et furanne prend de 3 à 5 jours), une dizaine de laboratoires répartis à travers le Canada sont mis à contribution pour donner le plus rapidement possible l'image de la situation.

L'INTERPRÉTATION

Quatre réalités sous-tendent la grille de base de l'interprétation des données recueillies.

1° La toxicité relative des BPC, dioxines et furanes.

La combustion incomplète des BPC génère habituellement des furannes chlorés. La combustion de matières organiques en présence de composés aromatiques halogénés peut aussi générer des dioxines. Or ces substances présentent des toxicités très différentes dépendamment des isomères en présence. L'isomère le plus toxique et le plus craint est sans contredit le 2,3,7,8-tétrachlorodibenzodioxine (2,3,7,8-T_4CDD). C'est en comparaison avec la toxicité de cet isomère que la toxicité relative des autres isomères a été établie.

La table de conversion en équivalent toxique utilisée est celle de U.S.E.P.A. (Tableau I).

2° L'existence d'un bruit de fond.

Après 100 ans d'activités industrielles intenses sur l'ensemble du globe, il est illusoire de croire qu'il existe encore des milieux protégés qui seraient exempts de toute contamination. Rappelons seulement que des traces de BPC ont été retrouvées dans les glaces du Pôle Nord et qu'il existe des quantités notables de BPC dans les échantillons de sol prélevés dans les milieux urbains et péri-urbains de l'Amérique du Nord.

Cette "contamination" de fond, le bruit de fond, résulte de sources diverses; les hepta et octachlorodibenzodioxines sont associées à ce bruit de fond. Il fallait donc en tenir compte lors de l'interprétation.

3° L'utilisation des critères de qualité du milieu.

Pour évaluer la qualité du milieu et les niveaux de contamination, les critères en usage en Amérique du Nord ont été utilisés (voir Tableau II).

En ce qui concerne les critères de frottis, ce sont des critères d'exposition en milieu industriel. Or on utilise généralement des critères 100 fois plus sécuritaires pour les milieux résidentiels. Pour tenir compte de ce fait nous avons considéré que les isomères en présence, dans les congénères autres que les tétra, étaient tous des isomères comportant des chlores aux positions 2,3,7,8 ce qui introduit un facteur de sécurité de l'ordre de 50 à 100. Dans le cas des têtra les isomères 2,3,7,8 étaient mesurés.

4° La détermination de la tendance générale de la contamination:

En date du 6 septembre, c'est-à-dire 3 jours avant la prise de décision, le ministère de l'Environnement disposait de 533 résultats d'analyse, ce qui représente environ 70 % des résultats attendus. (Tableau III). Ce qui était largement suffisant pour tirer des conclusions.

La zone à l'étude

Pendant la période où l'incendie a sévi, les vents soufflaient de l'est-sud-est avec des vitesses de l'ordre de 15 à 22 km/h. Le ciel s'est ennuagé en soirée et était couvert pendant la nuit. Un premier modèle de dispersion a été établi en prenant comme hypothèse que le contenu total de l'entrepôt a brûlé. La zone ainsi estimée de dispersion du panache de fumée à longue distance traverse l'est de l'Île de Montréal (Figure 2). Par la suite un modèle tenant compte des volumes estimés qui ont subi une combustion a été refait, ce modèle tient également compte de la morphologie du terrain (présence du Mont Saint-Bruno).

Air et frottis

Comme mentionné précédemment, des mesures d'air ambiant extérieur et intérieur ainsi que des frottis des surfaces exposées ont été réalisés dans les jours qui ont suivi l'incendie, afin de vérifier la qualité de l'air dans la zone évacuée et estimer l'importance des retombées du panache de fumée.

Air

Des mesures de BPC dans l'air ont été réalisées avec le TAGA 3000 (Trace Atmospheric Gas Analyser) du ministère de l'Environnement de l'Ontario. Le TAGA 6000 du ministère de l'Environnement de l'État de New-York a également contribué à établir le portrait de la qualité de l'air. Tous les prélèvements d'air à l'intérieur des écoles et des résidences étaient sous les limites de détection (100 ng/m^3).

Dans l'air extérieur, les teneurs en BPC se sont aussi avérées sous les limites de détection à l'exception de la proximité immédiate du site où l'on a trouvé suivant la direction des vents, des teneurs mesurables pouvant dépasser 100 ng/m^3. Un résultat d'analyse semble indiquer que les activités sur le site ont pu faire augmenter significativement les mesures de BPC dans l'air dans cette zone avant que les mesures d'atténuation ne soient mises en place.

Immédiatement après le feu, la concentration de BPC mesurée a été de 11 512 ng/m^3 et l'on a identifié surtout des T_4CDF, P_5CDF et H_6CDF, mais aussi un peu de dioxines (environ 4% de la quantité totale de PCDF de PCDD). Notons que ces dioxines sont en très faibles quantités et que ce sont les congénères H_6, H_7 et O_8 qui sont présents.

Par la suite au cours de la période du 26 août au 6 septembre, deux postes situés à environ 200 et 250 mètres de l'entrepôt incendié et qui étaient sous les vents dominants ont montré des valeurs variables de BPC, allant de 50 à 250 ng/m^3 (accumulation sur 11 à 50 heures). De faibles quantités de T_4CDF et P_5CDF et des traces de H_7CDD et O_8CDD ont été retrouvées.

Frottis intérieurs

On compte maintenant (en date du 29 septembre) 93 analyses de BPC et 43 analyses de PCDD et PCDF. La majorité des valeurs sont sous les limites de détection (BPC: 83/93; PCDD et PCDF: 36/43).

Les valeurs mesurées de BPC se retrouvent dans les secteurs de Saint-Basile-le-Grand (Nord) (1), Saint-Bruno (2), Saint-Bruno Trinité (4), Sainte-Julie Haut-Bois (2) et Sainte-Julie Nord (1).

Pour les 10 valeurs positives de BPC retrouvés, aucune ne présente toutefois de problème pour la santé puisqu'elles sont de 500 à 12 000 fois sous le critère retenu.

Les données de PCDD et PCDF sont exprimées en équivalent de toxicité de 2,3,7,8-T_4CDD. Le calcul a été fait avec les facteurs de l'EPA correspondant aux 2,3,7,8-P_5, 2,3,7,8-H_6 et 2,3,7,8-H_7 CDD et CDF.

Trente-six sur quarante-trois (36/43) analyses sont sous les limites de détection. Les valeurs positives retrouvées sont de 86 fois à 12 500 fois sous le critère de 0,25 ng/100 cm^2 et ne peuvent donc être considérées comme problématiques.

On ne retrouve que très peu de dioxines. Les hepta et octa sont les seuls congénères retrouvés. Quant aux furannes, on ne retrouve que les congénères T_4CDF. Dans tous les cas toutefois ces produits sont à peine mesurables par les appareils les plus sophistiqués. Les T_4CDF sont étroitement associés à la présence de BPC. Les hepta et octachlorodibenzodioxines sont associées au bruit de fond.

Frottis extérieurs

Nous disposons maintenant de 99 résultats de BPC et 23 résultats de PCDD et PCDF. De ce nombre 33 analyses de BPC sont au-dessus des limites de détection en incluant la série de 8 frottis à (# échant. 20 à 27) Sainte-Julie Haut-Bois (5) et Saint-Bruno (3) qui ont montré des valeurs extrêmement élevées, non confirmées par des échantillons parallèles.

Les valeurs positives de BPC sont retrouvées à Saint-Basile-le-Grand (Nord) (11/38), Saint-Basile-le-Grand (Est) (1/11), Saint-Bruno Trinité (1/4), Sainte-Julie Haut-Bois (5/13), Sainte-Julie Nord (1/8), Boucherville (1/7), Saint-Bruno (4/9) et le site (9/9). À l'exception de la série de valeurs élevées de Sainte-Julie Haut-Bois et Saint-Bruno, et des valeurs très fortes observées sur le site lui-même, et d'un échantillon de Saint-Basile-le-Grand (Nord) pris après la pluie, toutes les valeurs de frottis extérieurs sont sous le critère de 12,5 ug/100 cm^2 pour les BPC.

Les PCDD et PCDF ont été retrouvés dans 11 analyses sur 23, à Saint-Basile-le-Grand (Nord) (3/6), Saint-Bruno (1/3), Sainte-Julie Nord (1/1), Boucherville (1/1) et sur le site lui-même (5/5). Les valeurs ne dépassent pas le critère de 0,25 ng/100 cm^2 en équivalent toxique 2,3,7,8-T_4-CDD, à l'exception des analyses des édifices du site lui-même et d'un échantillon à Saint-Basile-le-Grand (Nord).

Les 3 frottis extérieurs de Saint-Basile-le-Grand (Nord) qui montrent des valeurs positives ont des profils semblables à ceux que l'on retrouve sur le site, dans la suie ou dans les échantillons d'air ambiant pris immédiatement après l'incendie; ceci montre que les furannes proviennent de l'incendie.

Gouttelettes d'huile

Des gouttelettes d'huile vaporisées lors de l'incendie et transportées avec le panache de fumée, se sont déposées sur les surfaces horizontales exposées (voitures, tables, etc.). Environnement Canada a évalué de façon quantitative l'étendue de cette dispersion. Les gouttelettes se retrouvent surtout le long d'un corridor s'étendant au nord-ouest de l'entrepôt sur une distance d'environ 1,5 kilomètre, à Saint-Basile-le-Grand (Nord).

Des échantillons d'huile ont été prélevés par frottis dans le quadrat où se trouvait le plus grand nombre de gouttelettes. Ces échantillons révèlent la présence de BPC et de congénères de furannes caractéristiques de l'incident (T_4CDF, P_5CDF et trace de H_6CDF) de l'ordre de deux fois inférieurs au critère d'exposition.

LES SOLS

1°. La signature de l'incendie

La signature de l'incendie est caractérisée par la présence de furannes (2,3,7,8-TCDF, TCDF, PCDF et H_6CDF).

On a retrouvé, dans les sols prélevés à proximité de l'entrepôt, des H_7CDD et OCDD. Ces formes de dioxines sont peu toxiques. Elles ont cependant été retrouvées dans tous les secteurs échantillonnés en concentration à peu près similaire ce qui nous laisse croire que leur présence est plus indicatrice du bruit de fond que du passage de l'incendie.

2°. Les zones

Les analyses de sol nous permettent de distinguer les zones suivantes:

- le site de l'incendie, fortement contaminé en BPC et contenant des furannes caractéristiques du feu;
- Saint-Basile-le-Grand (Nord) ou le passage du panache a laissé des traces perceptibles. On y retrouve 4 échantillons contenant des furannes. Transformées en équivalent toxique, ces concentrations de furannes sont de 25 à 300 fois sous le critère de qualité du milieu;
- Saint-Basile-le-Grand (Est), Saint-Basile-le-Grand (Sud), Sainte-Julie (Haut-Bois), Sainte-Julie Nord et Saint-Bruno où l'on a retrouvé dans quelques échantillons des furannes à des quantités souvent à peine supérieures à la limite de détection. Transformées en équivalent toxique, ces valeurs sont de 45 à 14 700 fois inférieures au critère de qualité du milieu;
- Saint-Bruno (Trinité) ou aucun échantillon ne s'est avéré contenir de furannes quantifiables en équivalent toxique.

EAUX DE SURFACE

Les eaux des fossés adjacents au site de l'incendie ont révélé la présence d'une forte contamination en BPC (380 à 6 900 ng/L). Des concentrations beaucoup plus élevées, de l'ordre de 17 000 et de 2 381 mg/L ont également été retrouvées dans des flaques d'eau échantillonnées à proximité immédiate de l'entrepôt. De l'huile échappée des barils se trouvait cependant dans ces échantillons d'eau, ce qui explique ces valeurs extrêmement élevées.

La présence de BPC a été détectée également dans les lacs Seigneurial et des Bouleaux et dans les ruisseaux Massé et Beloeil qui drainent le Mont Saint-Bruno à des concentrations allant de 1,0 à 39 ng/L. La présence de furannes dans ces lacs nous indique qu'il est fort probable que ces contaminants proviennent des retombées de l'incendie. Les concentrations mesurées de PCDD et PCDF, satisfont au critère intérimaire canadien de 15 pg/L (équivalent 2,3,7,8-T_4CDD) pour l'eau potable.

Les analyses démontrent donc que les niveaux de BPC, de dioxines et de furannes retrouvés dans les eaux de surface sur le Mont Saint-Bruno ne présentent pas de danger pour la santé humaine.

Toutefois, les niveaux mesurés excèdent les concentrations souhaitables pour la qualité de la vie aquatique.

EAU SOUTERRAINE

Les risques de contamination de l'eau souterraine dans la région de Saint-Basile-le-Grand ont été évalués. Du point de vue géologique, la région est constituée de quatre grandes unités stratigraphiques. La plus significative est sans doute une argile imperméable qui recouvre toute la plaine sur une épaisseur de 20 à 30 mètres.

L'eau souterraine est dans l'ensemble bien protégée de la contamination par la couche d'argile. Les sables des hautes terrasses, en contact direct avec la roche de fond, sont vulnérables mais se situent à des distances trop grandes pour avoir été contaminés.

Par ailleurs, un puits désaffecté, situé dans le garage municipal adjacent à l'entrepôt et tirant son eau à partir d'un aquifère localisé sous la couche d'argile, a été atteint par les eaux contaminées au moment de l'incendie.

Ce puits a été complètement vidangé (14 000 litres). Des prélèvements ultérieurs permettront d'identifier la persistance éventuelle de contaminants. L'accès au puits fut colmaté à l'aide d'une coulée en béton et les mesures de sécurité ont été prises afin de s'assurer qu'aucune autre infiltration de contaminants ne puisse survenir à l'intérieur du puits.

INTERPRÉTATION GLOBALE

Les résultats nous amènent donc à distinguer trois zones:

- le site de l'incendie, qui est fortement contaminé;
- Saint-Basile-le-Grand (Nord), zone à prioriser, où le passage du panache a laissé des traces;
- le reste de la zone évacuée qui ne présente pas de concentrations significatives de contaminants après le 25 août au niveau des composantes air, (air extérieur et frottis) et sol.

Dans cette zone on a détecté des BPC et des furannes à l'état de trace dans un corridor s'étendant jusqu'au Saint-Laurent. Les concentrations mesurées sont toutefois très faibles. Pour les sols, traduites en équivalent toxique, ces valeurs sont de l'ordre de plus de quinze mille fois sous le critère de qualité du milieu.

Après avoir pris connaissance de ces résultats, procédé à une analyse de risque et à la lumière des examens médicaux des personnes exposées, le Comité d'experts internationaux a émis le 9 septembre 1988 les recommandations suivantes:

1°. Les populations concernées peuvent dès maintenant réintégrer les zones évacuées, sans danger pour leur santé.

2°. Par prudence, les mesures de décontamination suivantes devraient être prises dans les zones résidentielles:

   a) nettoyage méticuleux des prises d'air des appareils de climatisation ou de ventilation qui fonctionnaient au moment de l'incident ou qui ont fonctionné pendant la période d'évacuation;

   b) dans les limites de la zone évacuée, lavage des surfaces extérieures et de toutes les surfaces potentiellement exposées aux fumées et aux suies de l'incendie, nettoyage des maisons, des véhicules, des patios et des autres surfaces dures, en particulier celles qui ne sont pas exposées à la pluie;

   c) recommandation de ne pas utiliser, à des fins d'alimentation humaine ou animale, les récoltes de légumes, les fruits et les baies provenant de la zone contaminée.

3°. Un programme de surveillance environnementale devrait être mis en oeuvre.

4°. Un programme de suivi épidémiologique et médical de l'ensemble de la population de la zone évacuée devrait être entrepris; ce programme devrait permettre de dépister une intoxication aiguë ou chronique, d'éventuels effets cliniques et, le cas échéant, des séquelles psychologiques.

5°. Un programme de suivi des effets pathologiques subaigüs et chroniques chez les personnes fortement exposées (groupes d'intervention et autres) devrait être mis en oeuvre.

6°. Un programme spécial de suivi vétérinaire des animaux se trouvant dans la zone contaminée devrait être entrepris.

7°. Des mesures devraient être prises pour améliorer la préparation des groupes d'intervention dans les cas d'accidents chimiques, notamment en ce qui concerne la coordination des mesures d'urgence. Ces plans d'intervention devraient préciser les responsabilités des différents individus et organismes concernés, et définir clairement l'instance chargée de la planification et de la mise en oeuvre des mesures requises.

8°. Les plans d'intervention devraient également prévoir le partage des tâches et des responsabilités de coordination, ainsi que des mécanismes permettant aux laboratoires d'analyse d'augmenter soudainement leur capacité de traitement des échantillons. Un système interne et inter-laboratoires de contrôle de la qualité devrait être élaboré.

9°. Il faut procéder à la décontamination du foyer d'incendie, de même qu'au transport et à l'élimination adéquats des déchets contaminés, en accordant une attention particulière à la santé et à la sécurité des équipes responsables de la réhabilitation du site.

10°. Ce Groupe ad hoc d'experts internationaux devrait procéder à une nouvelle évaluation de l'incident dans les six mois.

Le gouvernement du Québec a immédiatement donné suite à ces recommandations, entre autres en mettant sur pied un programme de suivi environnemental.

LE SUIVI ENVIRONNEMENTAL

Un programme de suivi environnemental est présentement en cours de réalisation.

Plusieurs organismes collaborent avec le ministère de l'Environnement du Québec à la réalisation du programme. Ce sont: Environnement Canada; le ministère de l'Agriculture des Pêcheries et de l'Alimentation du Québec; le ministère du Loisir de la Chasse et de la Pêche du Québec; ainsi que l'école polytechnique de l'Université de Montréal.

Le programme couvre les éléments suivants: l'eau, l'air, le sol ainsi que la faune et la végétation.

En ce qui concerne la qualité de l'air, six stations d'échantillonnage à grand débit opéreront jusqu'à la fin des travaux de restauration.

La qualité des eaux souterraines est actuellement suivie. Il en va de même pour la qualité des eaux de surface et principalement des eaux du lac du Moulin qui sert de réservoir d'appoint pour la municipalité de Saint-Bruno.

Des analyses seront effectuées sur des échantillons de sédiments, alevins et grenouilles pour déterminer s'il y a un impact au niveau des composantes de l'écosystème aquatique.

En ce qui concerne la végétation, des prélèvements de champignons et de pelouse serviront de bio-indicateurs.

La faune terrestre fera également l'objet d'un suivi. Les animaux analysés sont les suivants: des rats musqués, des musaraignes, des pigeons, des vers de terre, des lapins à queue blanche, de même que des gélinottes huppées.

De façon générale, il est prévu de procéder au dépistage des BPC pour l'ensemble des échantillons prélevés et d'effectuer les tests de dioxines et furannes sur le quart des échantillons.

Les résultats de ces analyses fourniront des indications sur la nécessité de poursuivre un programme de suivi à long terme et le cas échéant nous permettront d'optimiser le programme par la sélection des milieux les plus représentatifs.

NETTOYAGE ET RESTAURATION

Dans les heures qui suivent l'incendie, des travaux préliminaires sont entrepris pour éviter que des particules contaminées venant du site ne soient dispersées dans les champs, les quartiers voisins, les ruisseaux, la nappe d'eau souterraine, l'air ambiant.

Mentionnons entre autres choses:

a) La mise en barils de tous les débris de l'incendie,

b) le creusage de fossés et d'une lagune pour recueillir les eaux d'arrosage et les eaux de pluie,

c) la mise en opération d'une unité mobile de décontamination des eaux,

d) l'épandage d'une solution de chlorure de calcium pour éviter le transport de particules,

e) la construction autour du site d'une clôture de douze (12) pieds de haut pour contrôler l'accès,

f) la mise sur pied d'une unité de décontamination du personnel,

g) l'érection d'un chapiteau de 80 pieds par 120 pieds.

Le but de cette structure temporaire réalisée en vitesse vise à empêcher les eaux de pluie et les vents de transporter ailleurs des cendres, suies ou émanations contaminées jusqu'au début des travaux de restauration du site.

Lorsque le 9 septembre, à la suite de la recommandation des experts internationaux, le gouvernement autorise la réintégration des citoyens évacués, un programme de nettoyage des maisons, propriétés et édifices publics, est immédiatement enclenché pour éviter tout risque si mimime soit-il de contact avec des contaminants potentiels.

Le programme consiste "grosso modo" dans:

- le lavage au double jet d'eau savonneuse et d'eau claire des surfaces lisses des édifices, meubles de parterre, etc;

- la collecte des fruits et légumes des potagers et vergers domestiques;

- le nettoyage ou le remplacement des filtres à air des appareils de climatisation et thermopompes.

Ce programme s'est réalisé du 10 septembre au 26 septembre.

Plus de 2 500 maisons et propriétés privées sont nettoyées ainsi que toutes les infrastructures du Parc récréatif du Mont Saint-Bruno. On trouve au Tableau IV en annexe un bilan de ces opérations.

Le ministère de l'Agriculture du Québec pour sa part procède au déchiquetage et à l'élimination des produits végétaux provenant de 3 500 acres de terres agricoles commerciales.

La restauration du lieu de l'incendie reste l'opération la plus lourde et la plus complexe. Son exécution est prévue en deux étapes: d'abord la décontamination complète des lieux puis l'élimination sécuritaire des BPC et des autres éléments contaminés recueillis sur les lieux.

La première étape de cette opération est déjà en marche depuis le 6 octobre.

Les travaux consistent en:

- l'identification du contenu des barils, des transformateurs et des condensateurs;

- le nettoyage et la mise en sécurité à l'intérieur de conteneurs scellés des barils, des transformateurs et des condensateurs;

- le démantèlement de l'entrepôt et la décontamination des structures et du revêtement métalliques, de la dalle de béton et des rebuts métalliques;

- le démantèlement de l'abri temporaire (chapiteau) recouvrant l'entrepôt incendié;

- le traitement des eaux contaminées du site;

- le traitement et le recyclage des solvants usés.

L'exécution des travaux, qui fait l'objet d'un contrat de 6,6 millions $, est prévue pour la fin de l'année 1988.

Quant à l'élimination des BPC et des autres résidus contaminés résultant de cet incendie, ni le procédé de destruction qui sera utilisé, ni l'endroit, ni les coûts ne sont connus à l'heure actuelle. Les autorités gouvernementales ont donné l'assurance de cette élimination et d'intenses négociations sont en cours à ce sujet.

CONCLUSION

Le monde industrialisé a vécu plusieurs catastrophes écologiques attribuables en bonne partie à l'ignorance ou à l'inconscience reliée à la gestion des substances et déchets dangereux.

La société québécoise n'échappe pas à cette dure réalité. Citons quelques cas: la pollution par des huiles usées de la nappe phréatique de Ville Mercier, la démolition et la restauration d'un quartier résidentiel de Ville de LaSalle construit sur un ancien dépotoir, l'incendie de BPC dans les laboratoires de l'IREQ à Varennes et maintenant, l'incendie de l'entrepôt de BPC de Saint-Basile-le-Grand.

Quatre noms, quatre localités qui évoquent entre autres des dépenses de restauration de plusieurs dizaines de millions de dollars. Que de travail de prévention environnementale on aurait pu réaliser avec cet argent.

La société, les divers paliers de gouvernements, l'industrie, le monde scientifique apprennent à partir des catastrophes!

Celle-ci aura amené notre société et nos administrations à réaliser notre difficulté à réagir promptement et sans anicroche à un accident écologique majeur; à réaliser les limites de nos connaissances et de nos moyens! Elle aura contribué à raffermir la conviction des gouvernements de la nécessité d'adopter des lois et règlements beaucoup plus sévères pour gérer la manutention, le transport et l'élimination des déchets industriels dangereux et à affecter les ressources requises pour en assurer une rigoureuse application.

Elle aura signalé au monde scientifique la nécessité d'accélérer la recherche et le développement de ses connaissances en toxicologie, de mieux équiper ses laboratoires et de les normaliser.

Enfin, nous l'espérons, elle aura convaincu le monde industriel, de son rôle capital de gestionnaire des produits dangereux qu'il met en service, qu'il utilise dans ses procédés de fabrication et que trop souvent, il rejette sans traitement dans l'environnement.

Pour toute notre société, force est de constater qu'il en coûte moins cher de prévenir que de guérir.

ANNEXES

TABLEAU I Table de conversion en équivalent toxique (U.S.E.P.A.)

TABLEAU II Critères utilisés pour l'interprétation

TABLEAU III Bilan total des échantillons - Caractérisation environnementale à Saint-Basile-le-Grand

TABLEAU IV Bilan de l'opération nettoyage

FIGURE 1 Limites de la zone évacuée (Saint-Basile-le-Grand)

FIGURE 2 Zone estimée de dispersion du panache de fumée à longue distance (Saint-Basile-le-Grand)

TABLEAU I

TABLE DE CONVERSION EN ÉQUIVALENT TOXIQUE (U.S.E.P.A.)

Composé

PCDD

2378 T4CDD	1
Autres T4CDD	0,01
2378 P5CDD	0,5
Autres P5CDD	0,005
2378 H6CDD	0,04
Autres H6CDD	0,0004
2378 H7CDD	0,001
Autres H7CDD	0,0001
O8CDD	0

PCDF

2378 T4CDF	0,1
Autres T4CDF	0,001
2378 P5CDF	0,1
Autres P5CDF	0,001
2378 H6CDF	0,01
Autres H6CDF	0,0001
2378 H7CDF	0,001
Autres H7CDF	0,00001
O8CDF	0

TABLEAU II

CRITÈRES UTILISÉS POUR L'INTERPRÉTATION

	CRITÈRES		SOURCE	
MILIEU	BPC	DIOXINES ET FURANNES	BPC	DIOXINES ET FURANNES
Sol	1 mg/Kg	1 ug/Kg (équivalent 2,3,7,8 T_4 CDD)	Québec	États-Unis (EPA)
Eau Potable	100 ng/L	15pg/L (équivalent 2,3,7,8,T_4 CDD)	Québec	Canada
Air	450ng/m^3 (½ heure)	450pg/m^3 (½ heure)	Ontario	Ontario
	150ng/m^3 (24 heures)	-	Ontario	
	35ng/m^3 (1 an)	30pg/m^3 (1 an) $\text{(dioxines)}+\frac{\text{(furannes)}}{50}$	Ontario	Ontario
Frottis	2,5mg/m^2* (1242) 1,25mg/m^2* (1254 et 1260)	25ng/m^2	New York	New York

* AROCLOR 1242 (BPC à 42 % de chlore)
AROCLOR 1254 (BPC à 54 % de chlore)
AROCLOR 1260 (BPC à 60 % de chlore)

TABLEAU III

BILAN TOTAL DES ÉCHANTILLONS

CARACTÉRISATION ENVIRONNEMENTALE À SAINT-BASILE-LE-GRAND

NATURE	NOMBRE D'ÉCHANTILLONS	NOMBRE D'ANALYSES COMPLÉTÉES*
SOL	119	152 BPC 111 D-F**
FROTTIS EXTÉRIEURS	83	69 BPC 17 D-F
FROTTIS INTÉRIEURS	70	55 BPC 34 D-F
FILTRE À AIR	9	1 BPC 1 D-F
EAU	37	33 BPC 15 D-F
AIR	48	43 BPC 2 D-F
GRAND TOTAL:	366	353 BPC 180 D-F

* Dans plusieurs cas, les laboratoires ont procédé à l'analyse de duplicatas.

** D: dioxines
F: furannes

TABLEAU IV

BILAN DE L'OPÉRATION NETTOYAGE

NOMBRE	ZONE ÉVACUÉE	ZONES ADJACENTES	ZONE AFFECTÉE (MAPAQ)	TOTAL
PROPRIÉTÉS (incluant potagers et vergers)	1 696	831	——	2 527
VÉHICULES NEUFS (concessionnaires autos)	193	——	——	193
BÂTIMENTS (Parc du Mont St-Bruno, MAPAQ Pensionnat Sacré-Coeur)	38	——	——	38
FILTRES À AIR	195	39 *	——	234 *
TABLE DE PIQUE-NIQUE (Parc Mont St-Bruno)	225	——	——	225
RÉCUPÉRATION DE FRUITS ET LÉGUMES DES POTAGERS ET VERGERS (nombre de demandes zone affectée du MAPAQ)	——	——	109 *	109 *

* Situation au 1988/09/25

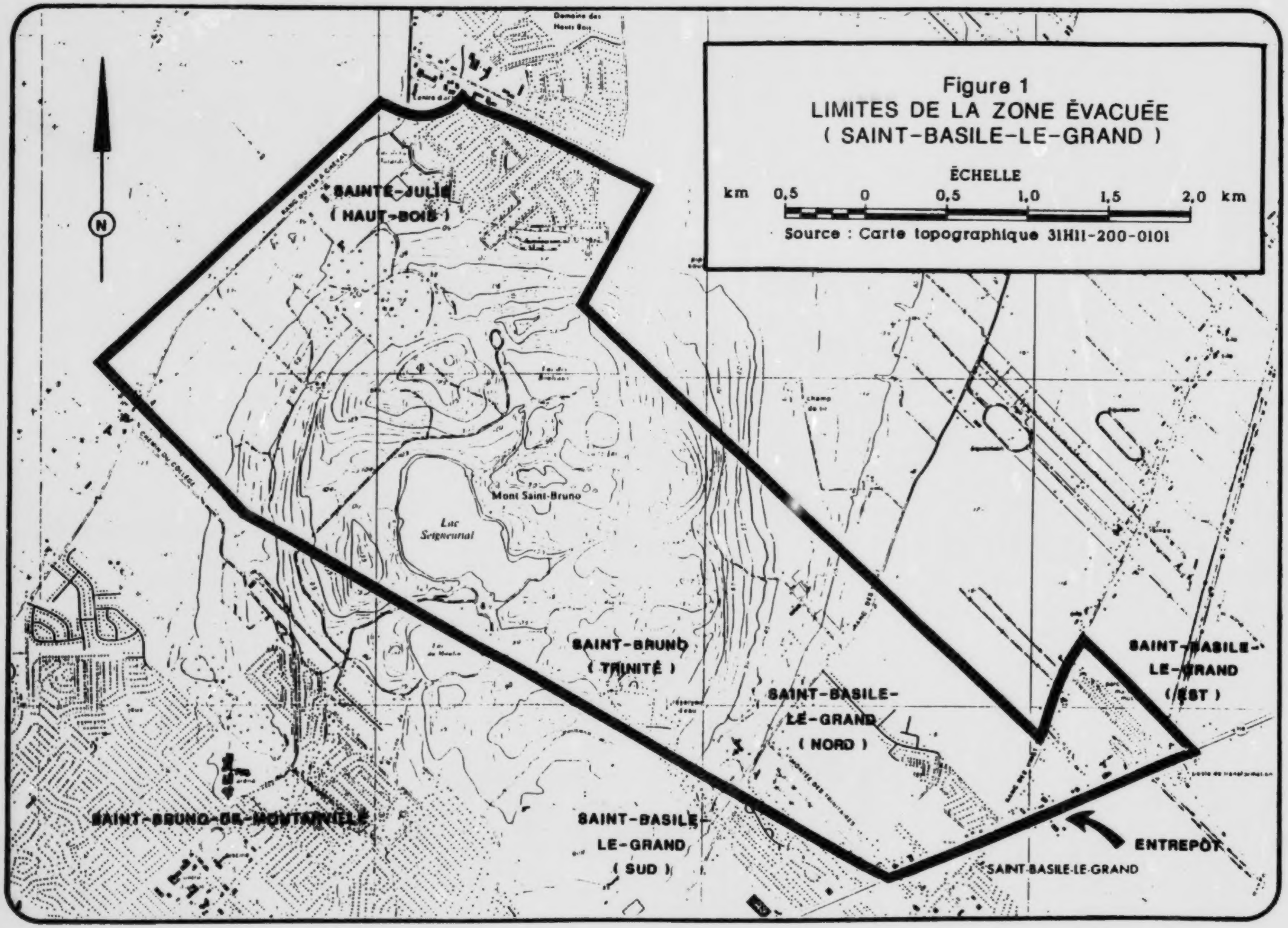

Figure 1
LIMITES DE LA ZONE ÉVACUÉE
(SAINT-BASILE-LE-GRAND)

ÉCHELLE
km 0,5 0 0,5 1,0 1,5 2,0 km
N
SAINTE-JULIE (HAUT-BOIS)
Domaine des Hauts Bois
Mont Saint-Bruno
Lac Seigneurial
SAINT-BRUNO (TRINITÉ)
SAINT-BASILE-LE-GRAND (NORD)
SAINT-BASILE-LE-GRAND (EST)
SAINT-BASILE-LE-GRAND (SUD)
SAINT-BRUNO-DE-MONTARVILLE
ENTREPÔT
SAINT-BASILE-LE-GRAND

Source : Carte topographique 31H11-200-0101

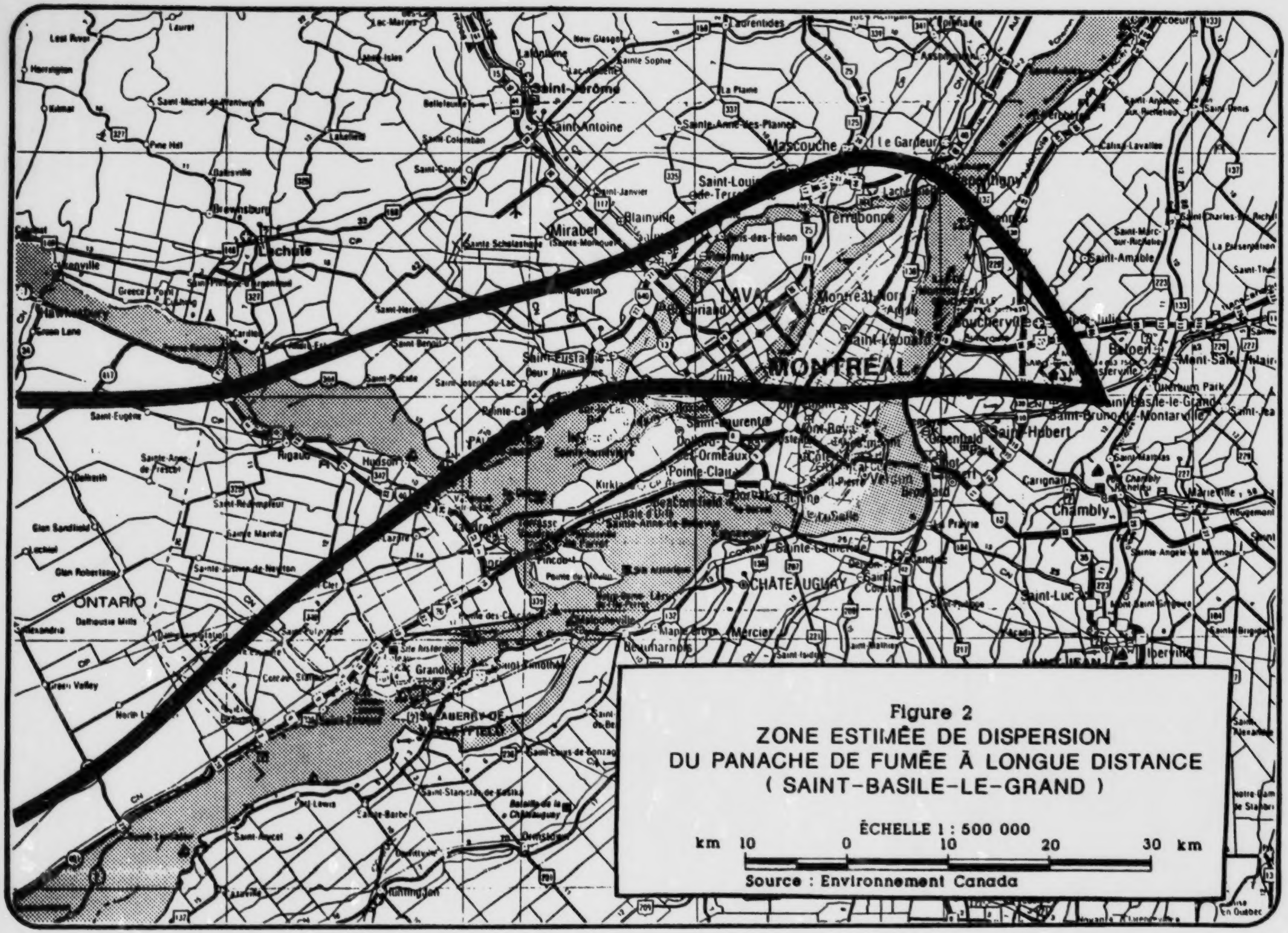
MONTRÉAL
LAVAL
Saint-Jérôme
Saint-Antoine
Mirabel
Lachute
Blainville
Mascouche
Le Gardeur
Terrebonne
Repentigny
Montréal-Nord
Saint-Léonard
Boucherville
Beloeil
Mont-Saint-Hilaire
Saint-Basile-le-Grand
Saint-Bruno-de-Montarville
Saint-Hubert
Saint-Laurent
Mont-Royal
Verdun
Brossard
Pointe-Claire
Beaconsfield
Dollard-des-Ormeaux
Châteauguay
Carignan
Chambly
Marieville
Saint-Luc
Iberville
Beauharnois
Mercier
Hudson
Rigaud
Hawkesbury
Salaberry-de-Valleyfield
Saint-Eustache
ONTARIO
km 10
0
10
20
30 km

Figure 2
ZONE ESTIMÉE DE DISPERSION
DU PANACHE DE FUMÉE À LONGUE DISTANCE
(SAINT-BASILE-LE-GRAND)

ÉCHELLE 1 : 500 000

Source : Environnement Canada

LABORATORY ACCREDITATION BY THE STANDARDS COUNCIL OF CANADA

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ABSTRACT

In 1970 the Standards Council of Canada (SCC) established the National Standards System (NSS) as a framework for managing standards work in Canada. The accreditation program for testing organizations is a critical component of the NSS. This paper reviews current accreditation criteria and requirements for testing labs and - since 1984 - calibration labs.

In its short history, this national laboratory accreditation program has witnessed phenomenal growth: the first accreditation was granted in 1981; 17 were accredited by 1984, and 45 by 1987. At this rate of growth, 500 labs will be accredited by the year 2000. The labs themselves clearly recognize the importance of this dynamic, national quality-management program.

The laboratory accreditation program cannot work without the cooperation of the labs and other supporting organizations. The paper concludes with a review of the benefits resulting from a proposed network of accredited calibration labs, and from the cooperation between the Department of National Defence, the National Research Council of Canada, and the SCC.

TEXT

Accreditation of a laboratory has been defined as official recognition of its ability to do specific tests or calibrations.

There are many reasons for setting up an accreditation program - improving client testing services; meeting the needs of regulatory authorities; meeting the needs of a parent corporation; etc. Frequently an accreditation program is established to fulfill contractual requirements between producers and users of goods and services. G.A. Berman reports that in the United States there are hundreds of formal and informal accreditation programs which have been established for this very reason [1]. Most are private programs which have been set up to evaluate and accredit the wide range of testing facilities in the U.S. Berman notes that often there is a great lack of similarity of criteria and procedures between the systems. The result is frequent duplication of assessments and audits, a practice which wastes increasingly-scarce resources.

There are many laboratory accreditation programs in Canada, but the average lab is not faced with as many audits or assessments as its U.S. counterpart. Some federal government departments run their own programs to ensure that manufacturers and service organizations meet the requirements of specific legislation or contracts. Provincial governments also run accreditation programs for laboratories which test products to provincial procurement specifications.

Many large manufacturers have their own laboratory accreditation programs to ensure that goods and services provided by suppliers will meet their needs. Some corporations have set up programs to satisfy the requirements of off-shore

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customers. There are also non-governmental, non-commercial groups, such as hospital associations or consumer organizations, which have set up laboratory accreditation programs. Again, such programs are aimed at ensuring that a more uniform, quality service is provided to users of their testing services.

The only accreditation program in Canada which covers laboratories in all fields of testing is that established by the Standards Council of Canada (SCC). The National Accreditation Program for Testing Organizations (NAPTO) is a truly national program which is open to all qualified laboratories in any field of testing or calibration.

A Crown corporation established in 1970 by an Act of Parliament, the Standards Council of Canada (SCC) coordinates voluntary standardization activities in Canada. The SCC was created in response to concerns that the previously ad-hoc approach to standardization was not adequate to meet the global challenge ahead. Factors contributing to this challenge included the growing importance of national and international trade, the increasing complexity of production and distribution of goods, and the rising pressure from consumer and environmental interests.

The SCC is not a government agency. It is financed primarily by an annual Parliamentary grant but is effectively independent of government in its operations, policies and procedures. With representatives from federal and provincial governments, and private sector groups interested in standardization, the 57-member Council establishes and implements the policies of the organization. As specified in the Standards Council of Canada Act, the role of SCC is to foster and promote voluntary standardization in Canada in order to advance the economy, benefit the health, welfare and safety of the public and consumers, facilitate trade and cooperate internationally in the standards field.

The SCC coordinates the National Standards System (NSS), a federation of independent organizations concerned with voluntary standardization which includes: (1) the SCC; (2) accredited standards writing, certification, and testing organizations; and (3) the Canadian National Committees on the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC).

The NSS implements SCC's mandated activities. Nationally, these comprise programs for the accreditation of standards-writing, certification, and testing organizations. Internationally, SCC is the Canadian member body on the ISO, sponsors the Canadian National Committee of the IEC and represents Canada at the International Laboratory Accreditation Conference (ILAC).

SCC's laboratory accreditation the program was implemented in 1980, with the first 2 labs accredited in 1981. As noted previously, it is open to all qualified labs in any field of testing. By qualified we mean:

- Located in Canada
- Competent in its field of testing or calibration
- Has suitable staff, facilities and procedures to meet SCC requirements.

Thus, size is not a criterion; competence is the main consideration.

By its very nature, an accreditation program is a dynamic, changing process. The SCC's laboratory accreditation program criteria and procedures are regularly reviewed and updated to meet the needs of changing technology. In addition, improvements may be made as a result of comments and suggestions from

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those involved at all stages of the accreditation process - SCC staff, lab staff, assessors, and the various technical, advisory and executive committees. The criteria and requirements for accreditation are spelled out in the document Accreditation Criteria and Requirements for Testing Organizations (CAN-P-4A, December 1984). It is still a generic document in that its criteria and requirements must all be met by any applicant for accreditation regardless of size or field of testing.

The intent of the program is that an accredited laboratory will be structured in a coherent manner with respect to the elements that produce and ensure quality testing services. These elements are covered by the criteria for the program described in CAN-P-4A as follows [3]:

(1) The organization shall have an administrative system capable of operating and maintaining the testing activity for which it is accredited.

(2) The organization shall be managed by people knowledgeable of test standards and test methods and professionally qualified to maintain records, manage and operate the testing activity for which it is accredited, and provide adequate reports.

(3) The organization shall have adequate facilities and equipment to carry out the testing activity for which it is accredited.

(4) The organization shall have documented and acceptable quality control procedures to ensure the integrity of its accredited testing activity.

(5) The organization, if subject to direct influence due to manufacturer or supplier interest, shall have acceptable procedures to ensure its objectivity and independence of operation from such interest.

As an aid to applicants, Guidelines for Preparing an Application for Accreditation (CAN-P-1510) was developed. This document follows the order of presentation of information in CAN-P-4A. It provides detailed information for those preparing an application by specifying what is required by CAN-P-4A generic statements, and by providing examples of the sort of information which should be supplied by the applicant.

In addition to the general information required about its operation, staff and procedures, an applicant lab must also specify the testing or calibration capabilities for which it is seeking accreditation. Once granted, the accreditation will relate only to those capabilities expressed in its scope of accreditation. Accreditation can only be granted for specific documented procedures, which include the following:

- Reference to test standards published by recognized standards-writing organizations.
- Documents containing pertinent information on equipment which constitutes the test method.

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- Documented specifications developed internally or derived from other test methods, provided they are in appropriate format and properly controlled.

- Specifications describing the scope and accuracy of measurement capabilities of a calibration laboratory.

The SCC accreditation process covers 6 basic steps. (1) Once an application is received, it is reviewed by SCC staff for completeness; (2) assessment is approved by the Testing Accreditation Sub-Committee. A suitable assessment team is assembled and (3) the on-site assessment of the applicant's facilities is then carried out. The purpose of an assessment is to confirm compliance with SCC's generic requirements, and to confirm the applicant's ability to do tests or make measurements for which accreditation is sought. Once non-compliance items identified during the assessment have been resolved (4), an assessment report is prepared (5) and is reviewed by technical and advisory committees before final accreditation is granted.(6)

The SCC coordinates all activities associated with the accreditation process, with an SCC staff member acting as the assessment team leader. For the technical evaluation of a lab's capabilities, SCC depends on volunteer technical experts who follow a peer group review process aimed at the "state of the art" for the industry, scientific discipline or technology in question.

Assessors get a solid grounding in the SCC criteria, requirements, and procedures as well as basic instruction on assessment techniques. Training includes showing them an SCC-produced video which describes the accreditation process with emphasis on the assessment. A formal assessor training program is planned for the future.

The assessors selected for an assessment must be acceptable to all parties concerned and will participate in the following activities during an assessment: (1) review of the applicant's operating procedures; (2) inspection of the physical facilities of the laboratory, for suitability; (3) confirmation that appropriate calibrated testing equipment is used by laboratory staff; and (4) verification of the ability of the applicant lab's staff to perform the tests for which accreditation is sought. This last item consists of having the applicant lab demonstrate a selection of tests representative of its scope of testing. Based on the summation of all these activities, a decision is then made on the applicant's accreditability.

Not all accreditation programs charge a fee to applicant laboratories; some users of goods and services set up programs specifically for their suppliers of testing or calibration services. For example, the Canadian Department of National Defence (DND) has a "recognition" program for calibration laboratories. DND charges no fees, but as a condition of recognition, laboratories must agree to provide services to the Department or to its military contractors.

Most other countries' national laboratory accreditation programs charge a fee, ranging from a minimal basic fee to complete cost recovery. SCC originally charged a flat fee of $500 to all applicants, regardless of size or scope of its testing or calibration capabilities. In January 1988, a revised fee structure was introduced. It included an application fee of $850, an annual renewal fee of $750 and a fee for expansion of the scope of accreditation ($350 when done during a scheduled audit and $600 if done between scheduled audits).

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Consideration is being given to including the extent of the scope of testing when setting application and renewal fees. Agreement has also been reached for taking the program towards full cost-recovery over a 10 year period. This will help ensure that the program is compatible with other national and international programs.

Since it was established in 1980, the program has seen tremendous growth. The first 2 labs were accredited in 1981; by 1984 17 were accredited and by the end of 1987 '45 labs were listed. Presently, 36 applications are being processed. At this rate of growth, it is expected that at least 500 labs will be accredited by the turn of the century.

This growth has come about for two reasons: first, recognition by labs that a national accreditation program will raise the quality of services offered to clients, and at the same time assure lab management that the lab is running a sound program. Second, users of testing services find they can have confidence in the services offered by SCC-accredited labs; indeed, some have done away with their own in-house arrangements and have specified the SCC program instead.

As noted earlier, a major drawback of duplicate accreditation programs is that labs are subjected to many, frequently unnecessary and costly, assessments and audits of their operations. In the past, there were major differences between the criteria and procedures of the many accreditation programs, often related to the rigorousness of the process. Some accreditors maintained their own programs simply because they felt it was their right, to "do their own thing" so to speak.

One of the results of the success of the SCC program is that users of testing services have been increasingly prepared to use SCC-accredited labs to provide testing or calibration services. Agreements for the acceptance of laboratories accredited by SCC have been signed between SCC and several large users of testing services, such as the federal Department of Consumer and Corporate Affairs and the Ministry of Transportation in the Province of Quebec. Discussions are currently underway aimed at the finalization of similar agreements between SCC and other major users of testing services.

One of the requirements of the SCC laboratory accreditation program is that testing equipment used by accredited labs be properly calibrated and that those calibrations be traceable to national measurement standards. Users of testing services must be able to depend on the accuracy of the test results they purchase; otherwise the whole testing process becomes meaningless.

Measurement-based activities surround us, allowing us to describe, predict, communicate, decide, control and react in dealing with the physical universe. For instance, dosage rates are important in safety and to the medical practitioner treating a patient. Legal Metrology at Consumer and Corporate Affairs Canada ensures gasoline pumps deliver known quantities of gasoline, or that electricity is supplied to consumers in accordance with statements of accuracy appropriate to the process. Measurements of water quality are being made in parts per million or billion. The latest defence systems demand optimum performance in order to perform successful missions. As a matter of interest, it is estimated that in Canada the annual value of measurement related activities is around 10 billion dollars; calibration and metrology have a significant affect on many diverse areas of our world.

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The accreditation of a calibration lab by SCC uses a two- pronged approach similar to testing lab accreditation: (1) verification of compliance with generic requirements; and (2) evaluation of technical capabilities. Following the receipt of an application, a visit is normally made to the cal lab to examine the equipment and physical facilities used to make the measurements. In addition, the scope of the lab's measurement capabilities is discussed in detail with the applicant's metrological staff, to ensure that stated claims are neither too conservative nor too optimistic. The metrological experts on the assessment team must have confidence in the cal lab's measurement abilities. To verify that the applicant lab is capable of making the required measurements, a number of well-characterized measurement devices or artifacts are submitted to the lab. The applicant must then make specific measurements to confirm its measurement capabilities and uncertainty claims. The reference lab supplying the measurement devices then analyzes the results. During the on-site assessment, the measurement results are discussed with the applicant and any problem areas are resolved. Technical advice is available to help the applicant overcome any difficulties identified in its operations, and to improve the general quality of measurement services provided to clients.

Continuing compliance of an accredited cal lab with the requirements and criteria for accreditation are verified through an audit program. An accredited lab is audited a year after accreditation and then every 2 years thereafter, as long as there have been no changes to key personnel, equipment or scope of accreditation. At each audit, a package of measurement devices representative of a portion of the scope is submitted to the registrant. In this way, a complete reassessment of the cal lab's measurement capabilities is carried out with every third audit.

The Department of National Defence (DND) operates a recognition program for cal labs. Where a laboratory applies to both DND and SCC for accreditation, a joint assessment of the applicant's facilities is arranged. DND supplies the package of characterized measurement devices, since SCC has no lab facility of its own. The expression of measurement capabilities of SCC-accredited cal labs is similar to DND's and is published in the SCC Directory of Accredited Testing Organizations (CAN-P-1550). The first cal lab was accredited by SCC in 1984. Presently 6 are accredited and applications from another 10 are being processed. Five of those first 6 were assessed jointly with DND.

The National Research Council of Canada (NRC) is responsible for developing, maintaining and disseminating primary standards of physical measurement in Canada. When a cal lab applied to SCC for accreditation but did not apply to DND for recognition, an up-until-recently informal agreement with NRC authorized NRC's Laboratory for Basic Standards to supply a suitable package of measurement devices. NRC and DND may also work together to assembly these measurement device packages, each contributing specific items which the other does not have access to at the time.

The excellent cooperative of DND, NRC and SCC has helped improve the quality of measurement services available in Canada today. In the context of this trilateral cooperative effort, and with a view to meeting the demand for enhanced calibration capabilities in Canada, the basis for a Canadian Calibration Network (CCN) has been established. This Network is a system for accredited calibration laboratories able to make measurements of physical quantities within defined uncertainties. The Network is administered jointly

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by NRC and SCC with significant input from DND. General procedures and criteria are based on SCC's lab accreditation program, but specific to organizations performing calibrations or precision measurements of physical quantities. The Network operates through an Advisory Committee which includes representatives of both NRC and SCC, along with individuals from other organizations, expert in the fields of metrology and laboratory accreditation.

To ensure compatibility with international standards and the International System of Units (SI), measurements made by accredited cal labs must be traceable to national measurement standards. In Canada, the NRC is the source of such traceability. It will provide measurement services and advice to all cal labs, as well as packages of measurement devices to cal labs applying to SCC for accreditation. NRC will also carry out annual technical audits of the accredited cal labs. All these activities will be coordinated by the recently-implemented NRC Calibration Laboratory Assessment Service (CLAS).

The SCC's role within the Network will be to verify that applicant labs meet the requirements of Accreditation Criteria and Requirements for Testing Organizations (CAN-P-4A). The staff of SCC will be responsible for coordinating the operational aspects of the Network, including secretarial support. The SCC will also have responsibility for granting accreditation and, upon acceptance, issuing a certificate of accreditation for specific fields of calibration or measurement. Support documents, provided by NRC/CLAS, will detail each quantity, instrument or gauge the lab is accredited to measure, the range of the quantity and any associated parameters or environmental conditions, the uncertainty of the lab's measurements and the chain of traceability to national measurement standards. The documents will include a statement that, within the accredited uncertainty level, the laboratory is capable of measurements equivalent to those reported by NRC.

The Network will support NRC's role of developing and maintaining a national base for the system of measurement units used in Canada and for ensuring direct traceability of measurements nationwide. In other words, such a Network will be the framework within which Canadian industry will have direct access to calibration services with verified traceability to national and international standards. As a key element in Canada's National Measurement System, this Network will benefit Canadian industry and trade directly, in the following ways:

- The need for precision measurement is growing in Canada and throughout the world. The Network will stimulate an increase in the quality of measurement science in Canada and the integrity of the National Measurement System. By enhancing measurement accuracy throughout the country, the Network will increase the quality of goods and services.

- By reducing waste caused by inaccurate measurements, the Network will improve productivity in manufacturing industries.

- By ensuring that measurements by accredited laboratories are traceable to NRC standards, the Network will ensure the compatibility of these measurements with international standards and the International System of Units (SI).

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- The requirement for accredited measurements, traceable to a national laboratory, is increasingly being made part of international contracts and written technical standards. By providing documented evidence of reliable calibrations, the Network will increase the competitiveness of Canadian companies in international commerce by enabling them to prove to their customers the reliability of measurements on which their products are based.

- By ensuring that, within defined uncertainty levels, measurements by accredited laboratories are equivalent to those reported by NRC, the Network will increase the availability of accurate measurements to the Canadian industrial community without putting an excessive load on the national laboratory.

SCC has developed a program with requirements and procedures in harmony with ISO and ILAC guidelines on laboratory accreditation. One of the goals for the program is to have SCC-accredited testing and calibration labs recognized and accepted by Canadian industry, government and other users of laboratory services, thereby reducing the need for duplicate assessments and audits on these labs.

The SCC program compares favorably with national programs around the world and we are confident that as the importance of international trade becomes ever more evident, so too will the need for a nationwide network of competent testing and calibration labs able to meet the demands of an expanding Canadian economy.

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[1] Berman, G.A., "ASTM Committee E-36 Activities in Standards Development for Laboratory Evaluation and Accreditation", Evaluation and Accreditation of Inspection and Test Activities, ASTM STP 814, Harvey Schock, Ed., American Society for Testing and Materials, 1983, pp 11-17

[2] Roué, J.E., "The Standards Council of Canada's Program for Accreditation of Testing Organizations", Evaluation and Accreditation of Inspection and Test Activities, ASTM STP 814, Harvey Schock, Ed., American Society for Testing and Materials, 1983, pp. 162-169

[3] Accreditation Criteria and Requirements for Testing Organizations, CAN-P-4A, Standards Council of Canada, December 1984

RECENT REGULATORY INITIATIVES IN HAZARDOUS WASTE CHARACTERIZATION

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PAPER OUTLINE

INTRODUCTION

° Two recent regulatory initiatives, one by the Ontario Ministry of the Environment (MOE) and one by the Working Group on TDG Hazardous Wastes (WG) which is responsible to the CCREM Waste Committee, have been undertaken with the intent of providing a more consistent and uniform basis for hazardous waste characterization; one is provincial in scope while the other is national in scope.

° The MOE initiative is the development of a Laboratory Qualification Code for the characterization of industrial waste according to Ontario Regulation 309, the provincial waste management regulation.

° The Working Group initiative is the development of a Canadian Extraction Procedure (CEP) for the characterization of leachate toxic waste.

° Both the Qualification Code and the Extraction Procedure are being developed through the process of technical consensus.

ONTARIO REGULATION 309 LABORATORY QUALIFICATION CODE

° Concept originally conceived in 1984.

° Terms of reference finalized in 1986 and contract awarded in August, 1986.

° Two phase approach:

Phase 1. - Development of the draft qualification code document by the contractor.
Establishment of a technical committee to refine the document.
Phase 2. - Finalization of the code through the process of consensus standard development.

° Purpose: to develop a qualification standard for laboratories analyzing, or intending to analyse, industrial waste for characterization under Regulation 309; the standard is being developed by a consensus approach and is to be capable of being used with any subsequent certification programs that the Ministry of the Environment may wish to proceed with at a future date.

° Draft standard prepared by the contractor and submitted in March, 1987.

° Membership of technical committee finalized, consistent with make-up indicated below:

Regulatory Authorities (4-6 persons)
- Environment Canada
- Ontario Ministry of the Environment.

User Interests (5-7 persons)
- Laboratories carrying out analysis according to the standard

Producer Interests (5-7 persons)
- Waste generators
- Waste management industry

General Interests (5-7 persons)
- Ontario Waste Management Corporation
- Academia
- CSA certification & testing
- Industry association
- Consumers

° Technical committee convened initially in August, 1987.

° Five sub-committees established to address the following aspects.

i) Laboratory Requirements - Management
Quality Assurance/Quality Control
Staffing
Facilities
Instrumentation
Documentation

ii) Leachate Extraction Procedure*

iii) Physical Test Methods - Slump* (liquid/solid)
Corrosivity*
Ignitability*
Cyanide/sulphide bearing waste analysis

iv) Inorganic Test Methods - Primarily Regulation 309 Schedule 4 parameters

v) Organic Test Methods - Primarily Regulation 309 Schedule 3, Schedule 4 parameters

* Methods for these characteristics are prescribed in Regulation 309.

° Committee members proceeded to finalize the code according to the terms of reference, recognizing that by virtue of being incorporated in a regulation some test methods could not be altered and flexibility was somewhat restricted.

° Consensus of members of the technical committee was the basic criteria in preparing the final product.

° Critical review of regulated methods and procedures was invited by MOE, and the technical committee will be responding in a separate report.

° The Code has been finalized by the technical committee and is at present undergoing the standards setting process.

° Anticipated publication/availability - January, 1989.

- The future of the code:

  Initially:
  - make generating community and laboratories aware of its existence and purpose (ie. education)
  - recommend that generator registration applications be accompanied by waste characterization data produced by laboratories who state in writing that they have followed the code.

  Possible next step:
  - require by regulation that only analytical data produced according to the code be acceptable for generator registration and other waste characterization applications.
  - formalize a laboratory accreditation program under the administration of a national standards setting body including auditing.

THE CANADIAN EXTRACTION PROCEDURE

° Federal Transportation of Dangerous Goods Act passed in 1980; regulations under the Act promulgated in 1985.

° The Working Group on TDG Hazardous Wastes, part of the CCREM committee/working group structure, developed and submitted in March 1986 a draft amendment package addressing several hazardous waste issues.

° The package, consisting of
- expanded definitions for hazardous wastes
- clarification of existing criteria
- a new "leachable toxic waste" classification

was published in a Transport Canada Special Bulletin in June 1987.

° A provisional extraction protocol, published by the Canadian General Standards Board (CGSB), along with a schedule of contaminants and regulated levels, was referenced in the proposed amendments.

° The protocol, adopted by several provinces and essentially identical to those in use in some other provinces at present, was based on the U.S. EPA's EP Toxicity test procedure.

° The Working Group is charged under the CCREM Hazardous Waste Action Plan (HWAP) Task 1.3 to develop and improve TDG regulation testing protocols; one such protocol is a leachate extraction procedure(s) under TDGA for the characterization of leachate toxic waste.

° Based on a previous study initiated by the Working Group, it was deemed that the U.S. EPA's proposed Toxic Characteristic Leaching Procedure (TCLP) offered the most promise as a basis for the CEP due to its features addressing organic contaminants and volatile organics.

° A TDG Working Group project was approved to direct a study to develop a standard leachate extraction procedure for Canada.

° A workshop of experts was convened in Cornwall, Ontario in March 1988 to address this objective.

° The Workshop
- 25 experts in leachate extraction procedures, toxicology and waste management policy from Canada, the United States and Europe
- Moderated by a professional facilitator and carried out according to a format of plenary presentations/discussion and concurrent small group discussions

- Three (3) small groups with representation from technical experts in leachate extraction procedures and toxicology, and federal and provincial regulators.
- Prior to the workshop the consultant compared 5 leachate extraction protocols:
  - . U.S. EP Toxicity Test
  - . Ontario Regulation 309 Test
  - . U.S. TCLP - Toxic Characteristic Leaching Procedure
  - . Quebec R.s.Q.,Q-2,R. 12-1
  - . CGSB 164-BP-IMP

  and contacted several participants and non-participants to solicit comments, constructive criticism and identify issues for discussion/resolution at the Workshop.
- Based on this research, the consultant summarized twenty issues under the broad groupings of:
  - . sampling and sample preparation
  - . extraction
  - . analysis
- The issues discussed are summarized in Appendix 1.

° Following small group and plenary discussion on all these issues, consensus was solicited and generally obtained

° Where consensus was not possible both majority and minority recommendations were recorded

° Based on the results of the Workshop and using the U.S. TCLP as a basis, a Canadian Extraction Procedure (CEP) was drafted.

° The key aspects of the draft CEP compared to the TCLP and other procedures used in Canada at present are:
- volatiles not addressed by the procedure
- liquid to solid ratio of 20:1
- phase separation prior to extraction
- acidic and distilled water extraction fluids
- provision for toxicity testing

° In comparing the draft CEP to other procedures in use at present in Canada it was evident that further study was required in three areas:
- liquid to solid ratio
- phase separation prior to extraction
- composition of acidic extraction fluid

° The TDG Working Group prepared terms of reference for a study to assess extraction procedures for the purpose of validation; this was deemed necessary prior to any recommendation for use as a national standard protocol.

° Anticipated recommendation to the CCREM Waste Committee by March 31, 1989.

SUMMARY

This paper does not report on the details of a final product as both documents have yet to be finalized.

The most important messages of the paper, beyond informing the waste management communities of the existence of these two initiatives, is to assure the stakeholders that government is involving them in policy-making at the grass roots level and is striving to develop realistic and practical policies and legislation consistent with the protection of human health and the environment and that federal and provincial governments are working together to develop uniform national hazardous waste policies through CCREM initiatives including the Hazardous Waste Action Plan.

ACKNOWLEDGEMENTS

The authors would like to gratefully acknowledge the financial contribution of the Ontario Ministry of the Environment and Environment Canada, the contributions of the individuals assisting in project management including Steven Radcliffe (MOE), Tom Constable (Environment Canada), Serge St. Laurent (Environment Quebec), Neil McQuaker (B.C. Environment) and Bob Redhead (Tricil), the efforts of the two consultants, the Canadian Standards Association (Lab Code) and Energy Pathways Inc. (Extraction Procedure Workshop) and the participants in the CSA Technical Committee and the Extraction Procedure Workshop.

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Appendix 1

Issues Considered at the Extraction Procedure Workshop

Sampling and Sample Preparation

Sampling protocol to be specified.

Sample handling and preservation methods to be specified.

Should the protocol incorporate structural integrity testing? If so, what procedure should be used to test structural integrity?

What should the minimum sample size be? Should it be subsampled from a larger sample, and if so, how? Is it acceptable to use a smaller sample size when testing for volatiles? If not, how can equipment restrictions be circumvented? Should the sample size be based on wet or dry weight?

What is an appropriate particle size for free-flowing wastes?

Should solid and liquid phases be separated above 0.5% solids in suspension? If so, should the 0.5± limit be calculated on a dry solids or solid phase basis? On a weight/weight or weight/volume basis?

What type of filter should be specified? Should prefilters be used? Should any special approaches be specified for oily wastes?

Extraction

How should the protocol deal with volatiles? Should use of the ZHE or equivalent equipment be required? Is the TCLP ZHE acceptable or should some other type of equipment be specified?

What extraction fluid(s) should be specified?

What should the liquid-to-solid ratio be? How should it be calculated (dry solids vs undried)?

What elution time should the protocol require?

What equipment is most suitable for agitation? What should be the speed of rotation?

What temperature or range of temperatures should be specified?

What materials should be specified for vessel construction?

Analysis

What separation procedures and apparatus should be specified?

Should the liquid phases of the leachate and original sample be combined? If so, should they be combined physically prior to analysis or by combining results mathematically after analysis?

What procedures should be specified for extract handling and analysis?

Should provision for toxicity testing, either currently or in the future, be incorporated into the standard protocol? What implications does this have for choice of extraction fluid?

Should the protocol state that extraction need not be carried out if total analysis of the waste shows that the appropriate regulatory thresholds could not be exceeded?

What quality control provisions should be incorporated into the protocol?

Appendix 2

Glossary of Terms

MOE	Ontario Ministry of the Environment
CCREM	Canadian Council of Resource and Environment Ministers - representation from federal government plus all provinces
WG	Working Group on Transportation of Dangerous Goods (TDG)
Regulation 309	waste management regulation under the Ontario *Environmental Protection Act*
CEP	Canadian Extraction Procedure
CSA	Canadian Standards Association
Schedule 3	Regulation 309 listing of Severely Toxic organic wastes
Schedule 4	Regulation 309 Leachate Quality Criteria
TDGA	federal *Transportation of Dangerous Goods Act*
CGSB	Canadian General Standards Board
U.S. EPA	United States Environmental Protection Agnecy
EP Toxicity Test	leachate extraction procedure developed by the U.S. EPA for the characterization of potentially hazardous wastes
HWAP	Hazardous Waste Action Plan developed by CCREM
TCLP	Toxic Characteristic Leaching Procedure developed by the U.S. EPA
ZHE	Zero Headspace Extractor

RESTAURATION DE L'ANCIEN DÉPOTOIR DE LASALLE

Serge Goulet
Ministère de l'Environnement du Québec

Des maisons sur un dépotoir toxique: 10 millions $ pour la restauration, 8 maisons multifamiliales démolies, 90 personnes quittant le quartier, 130 000 m^3 de sols contaminés, voilà le bilan sommaire de la restauration de l'ancien dépotoir de LaSalle! Voyons maintenant dans un ordre chronologique le déroulement des événements.

INTRODUCTION

Le ministère de l'Environnement du Québec a crée, en 1983, le groupe GERLED qui a eu pour mandat d'inventorier les lieux représentant un potentiel de risque pour la santé humaine et l'environnement et d'établir des priorités d'action pour la caractérisation et la restauration de ces lieux.

C'est lors de cet inventaire que le lieu de l'ancien dépotoir fut identifié.

L'enquête qui suivit, ainsi que les premières études du site, nous permirent de retracer l'historique de l'ancien dépotoir de LaSalle.

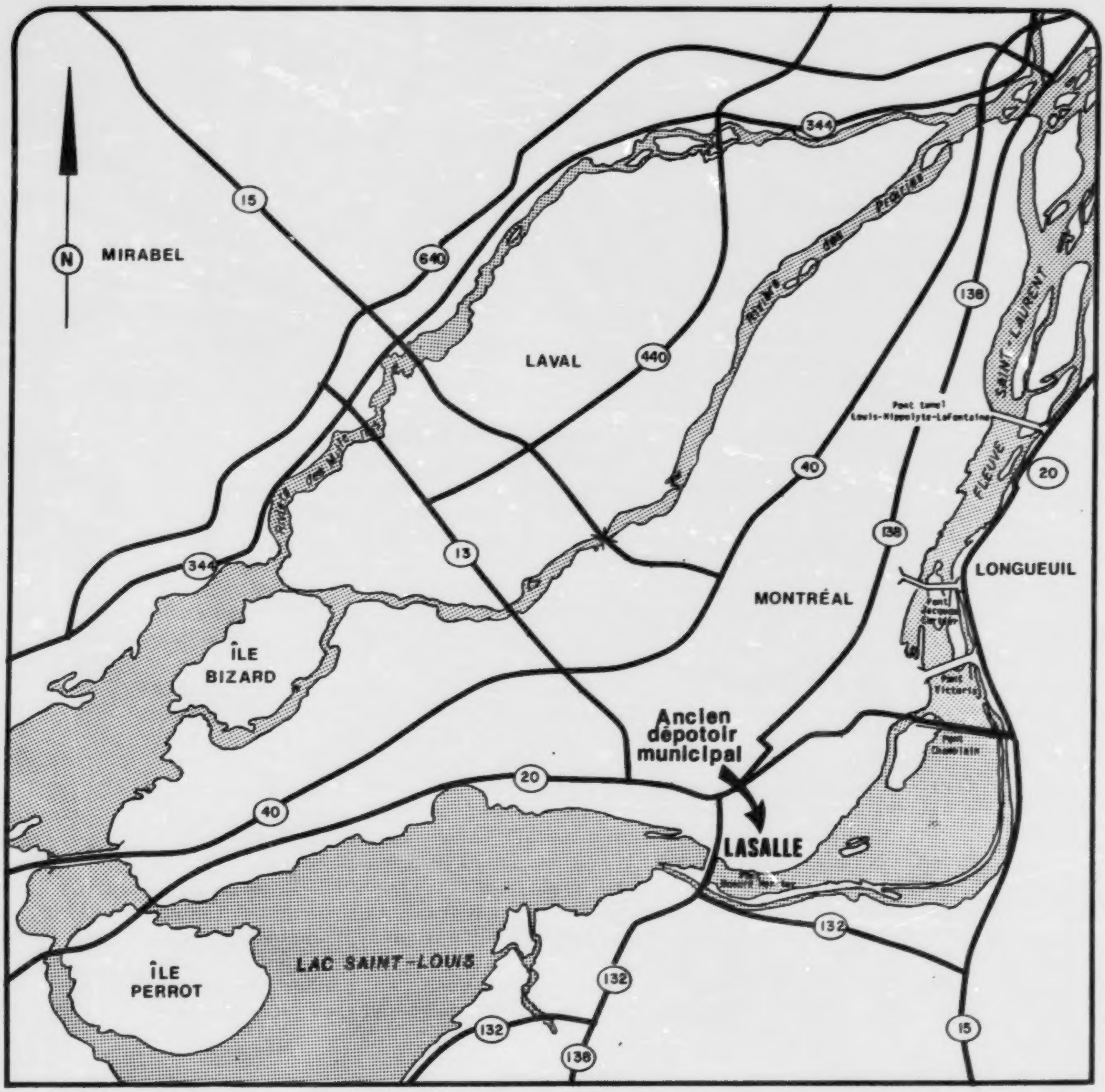
À partir de 1940 et pendant vingt ans, la ville de LaSalle a exploité un dépotoir qui reçut, en plus des déchets domestiques, une grande quantité de déchets industriels. Ces déchets industriels ont été déposés, soit en barils, soit en vrac, dans des tranchées creusées spécialement à cette fin dans un secteur situé au sud-ouest du dépotoir de déchets domestiques.

L'analyse des photographies aériennes et des relevés d'arpentage nous indique qu'il y a eu un nivellement du sol dans le secteur peu après la fermeture du dépotoir en 1960. Cette opération de nivellement entraîna l'excavation des déchets industriels et des sols contaminés du secteur des tranchées. Ces sols et déchets furent transportés plus à l'ouest, comblant une dépression topographique. Plus tard, dans les années soixante, le quartier fut développé à des fins commerciales et résidentielles.

COMITÉ DE COORDINATION

Après que les études préliminaires confirmèrent la présence de déchets toxiques sous un quartier résidentiel de la ville, le ministère de l'Environnement, préoccupé par la sauvegarde de la santé des citoyens, mis sur pied un comité de coordination dont le mandat était:

- d'assister les citoyens touchés (pour les aspects: santé, logement et assistance financière);
- de procéder aux études de caractérisation; et
- de voir à la restauration du lieu contaminé, si cela s'avérait nécessaire.


N
MIRABEL
15
640
344
LAVAL
440
Rivière des Prairies
Rivière des Mille Îles
138
SAINT-LAURENT
FLEUVE
Pont tunnel Louis-Hippolyte-LaFontaine
20
40
13
138
LONGUEUIL
MONTRÉAL
ÎLE BIZARD
Pont Jacques Cartier
Pont Victoria
Pont Champlain
Ancien dépotoir municipal
20
40
LASALLE
Pont Honoré-Mercier
132
ÎLE PERROT
LAC SAINT-LOUIS
132
132
138
15

LOCALISATION DE L'ANCIEN DÉPOTOIR DE LASALLE

ÉCHELLE 1:250 000

0 5 10 15 Km

Source : Ministère des Transports du Québec
La carte routière du Québec, 1985

Ce comité regroupait les experts en toxicologie environnementale du Québec et des intervenants de la santé, ainsi que des représentants de la ville et des différents Ministères concernés. Le comité privilégia une approche d'ouverture avec les citoyens en les tenant informés lors de réunions spéciales et par la distribution d'un bulletin d'information.

LES ÉTUDES DE CARACTÉRISATION

Qualité du sol

Au cours de la campagne d'échantillonnage du sol de l'été et de l'automne 1985 réalisée par le ministère de l'Environnement, 400 échantillons de sol ont été récupérés et la moitié de ceux-ci furent analysés. La recherche de 104 paramètres organiques reconnus prioritaires par la U.S.E.P.A. a été effectuée sur ces échantillons de sol. Les analyses ont révélé la présence de 61 de ces polluants organiques toxiques.

Les principaux contaminants sont des hydrocarbures polycycliques aromatiques (HPA), des biphényles polychlorés (BPC), des composés phénoliques et des hydrocarbures monocycliques aromatiques (HMA). Des dioxines et des furannes ont également été détectées dans le sol. La concentration des contaminants varie considérablement, atteignant plus de 20% en poids dans des échantillons de sols saturés en goudrons.

Les résultats d'analyses ont ainsi permis d'identifier un volume de 130 000 m^3 de sols contaminés, répartis sur une superficie d'environ 26 000 m^2.

Qualité de l'eau souterraine

L'analyse des données recueillies lors de l'étude hydrogéologique, réalisée par Foratek International inc. avec la collaboration de la firme Cartier-Monenco, a permis d'identifier la présence de 24 composés organiques. La contamination en composés organiques mise en évidence est principalement constituée d'hydrocarbures polycycliques aromatiques (HPA). On retrouve également du benzène, du totulène et des xylènes, de même que des biphényles polychlorés (BPC). La contamination de type inorganique se résumait, quant à elle, à la présence de baryum, de mercure, de zinc, de vanadium et de cadnium.

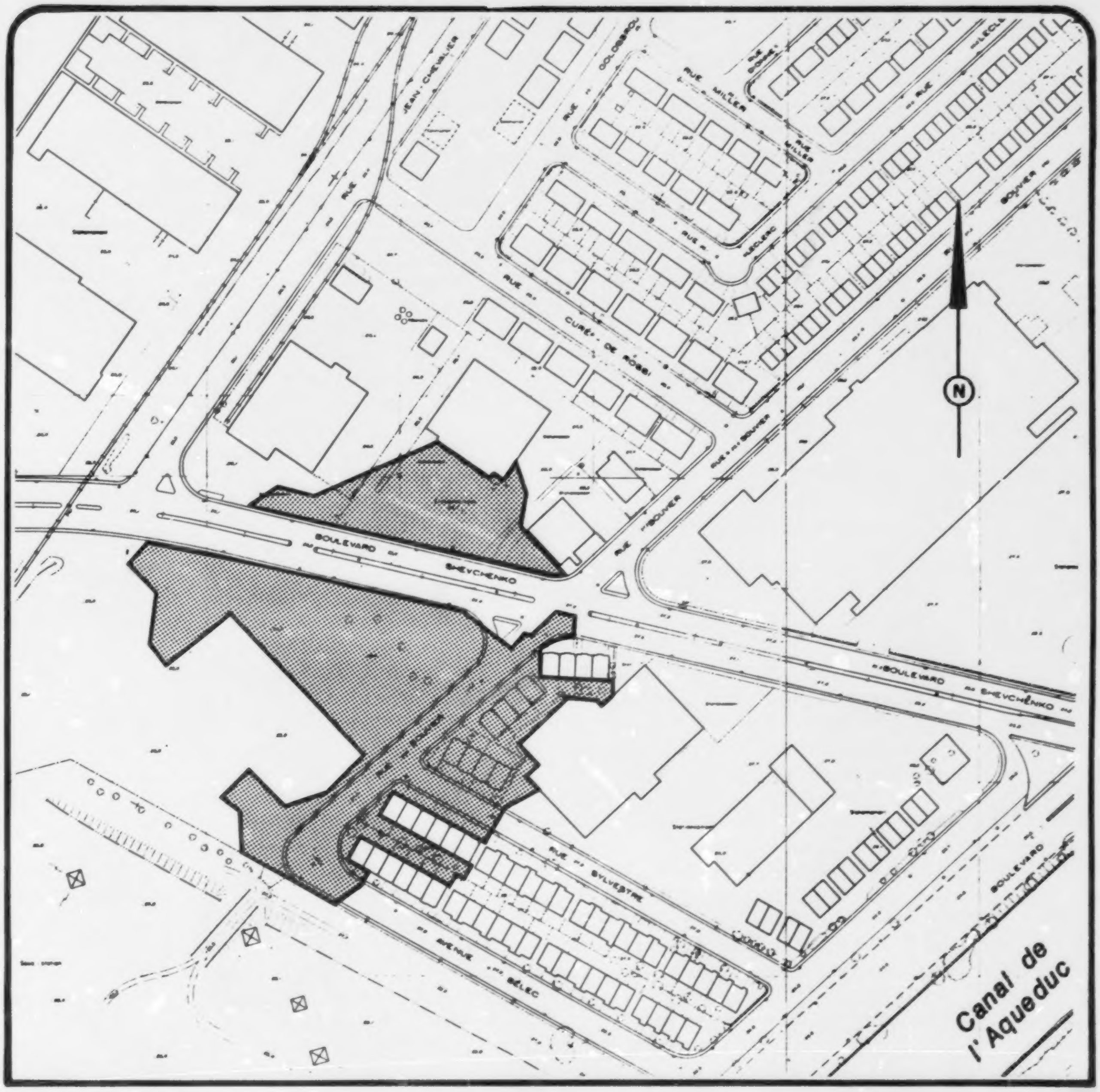
Une particularité de l'étude hydrogéologique fut de démontrer que le front de contamination se dirigeait vers le canal de l'Aqueduc, situé à quelques 100 m en aval, lequel représente l'une des deux sources pour l'alimentation en eau potable de la ville.

Qualité de l'air dans les résidences

Une étude de la qualité de l'air à l'intérieur des maisons fut réalisée sous la supervision d'Environnement Canada. Cette étude consistait à identifier et à quantifier les composés organiques volatils présents à l'état de traces dans l'air ambiant des maisons situées au-dessus de la zone contaminée et à compa-

Fréquence d'apparition des principaux contaminants dans le sol

CLASSE	CONTAMINANTS	FRÉQUENCE D'APPARITION
HAP	Phénanthrène	28%
HAP	Benzo (a) Pyrène	25%
HAP	Benzo (a) Anthracène	23%
HAP	Fluoranthène	22%
HAP	Pyrène	19%
HAP	Anthracène	19%
HAP	Benzo (b + k) Fluoranthène	19%
HAP	Chrysène	18%
HAP	Naphtalène	18%
HAP	Fluorène	14%
PHÉNOLS	2,4 Diméthyl phénol	14%
HC	Biphényles polychlorés	13%
	Autres:	
CAM	Éthylbenzène	5%
CAM	Benzène	3%
CAM	Toluène	3%


RUE JEAN-CHEVALIER
RUE MILLER
RUE LECLERC
RUE CURÉ-DE ROSSI
RUE BOUVIER
BOULEVARD SHEVCHENKO
RUE SYLVESTRE
AVENUE BÉLEC
BOULEVARD
N
Canal de l'Aqueduc

ZONE DE SOL CONTAMINÉ

Sources : – Ministère de l'Environnement du Québec
Direction des substances dangereuses

– André Marsan et Associés

ÉCHELLE

0 25 50 75 100 125 150 metres

M.E.R. feuillets 31H05-010-2931,2932
31H05-010-3031, 3032

rer les résultats avec ceux obtenus dans des maisons témoins situées à l'extérieur de cette zone.

Les conclusions de cette étude furent que:

- les contaminants détectés dans l'air des maisons sont, dans tous les cas, très faibles;
- il n'y a aucune différence significative entre les valeurs mesurées dans la zone-cible et celles de la zone-témoin.

Conclusion des études de caractérisation

Les résultats des études réalisées n'ont fourni aucune évidence d'une exposition de la population aux contaminants. Cependant, considérant les effets négatifs appréhendés sur la population et sur le milieu à court, à moyen et à long terme des contaminants présents dans le sol et l'eau souterraine et considérant le caractère imprévisible de l'évolution de la contamination, le Gouvernement du Québec et la ville de LaSalle prirent la décision d'intervenir pour solutionner le problème.

LES TRAVAUX DE RESTAURATION

Mesures de protection

Les travaux de restauration de l'ancien dépotoir de LaSalle, réalisés sous la surveillance de la firme Lavalin Environnement, débutèrent en juin 1986 et furent terminés dix (10) semaines plus tard. L'exécution de ces travaux a nécessité des mesures particulières afin d'assurer la protection des travailleurs et des citoyens vivant à proximité de l'aire des travaux, étant donné que l'emplacement de l'ancien dépotoir est situé dans un milieu fortement urbanisé.

Ainsi, la protection des travailleurs du chantier était sous la responsabilité de la Commission de la santé et de la sécurité du travail (CSST) et du Département de santé ommunautaire (DSC) de Verdun.

En ce qui concerne la protection des citoyens, plusieurs mesures ont été mises en place. Premièrement, le périmètre de l'aire des travaux fut clôturé pour minimiser le transport des poussières. Par endroit, cette clôture atteignait 5m de hauteur. Deuxièmement, un contrôle de la qualité de l'air ambiant dans le quartier fut réalisé à l'aide d'un laboratoire mobile (TAGA 3000). Ce laboratoire mobile, appartenant au Ministère fédéral de la santé et du bien-être social, quantifiait la concentration des paramètres les plus abondants et les plus problématiques susceptibles d'être dégagés dans l'air lors des travaux d'excavation. Il nous a permis de s'assurer qu'en aucun temps, la concentration des contaminants analysés n'a excédée les normes prescrites ou même approchée les critères d'évacuation. Troisièmement, des échantillonneurs à grand débit ("High volume") ont été installés afin de mesurer la quantité de poussière dans l'air ambiant.

Démolition des maisons

Les travaux d'excavation entraînèrent la démolition de huit (8) résidences multifamiliales situées directement au-dessus de la zone contaminée et l'achat, par la ville, de six (6) autres résidences multifamiliales situées à proximité immédiate de cette zone contaminée. Quatre vingt dix (90) personnes ont ainsi quitté définitivement ces quatorze (14) maisons. De plus, les travaux entraînèrent également la relocalisation temporaire des soixante cinq (65) occupants de dix (10) autres habitations multifamiliales, de juin à septembre 1986.

Excavation des sols contaminés

Les 130 000 m^3 de sols contaminés furent excavés sur une superficie d'environ 26 000 m^2 et sur une profondeur moyenne de 5 m à l'aide de pelles hydrauliques. Le transport des sols contaminés du chantier au lieu d'enfouissement sécuritaire a nécessité plus de 10 000 chargements de camions et les roues des camions étaient nettoyées avant de quitter le chantier.

Décontamination de l'eau

Les eaux souterraines, les eaux de ruissellement ainsi que les eaux de lavage des camions étaient recueillies dans les canaux de drainage puis acheminées vers une unité mobile de traitement pour y être décontaminée. Au total, 6 600 m^3 d'eau furent décontaminés par cet unité de traitement dont l'unité principale était un ozoniseur.

LIEU D'ENFOUISSEMENT SÉCURITAIRE

Les sols contaminés furent transportés sur une distance de 4 km, au terrain de l'ancienne usine "LaSalle Coke" pour y être enfouis sécuritairement. Ce terrain fortement contaminé a déjà fait l'objet de restauration partielle dans le passé et l'on y retrouve quatre (4) cellules, regroupant plus de 100 000 m^3 de sols contaminés. La restauration finale de ce site a d'ailleurs été entreprise cette année et sera complétée l'année prochaine.

Une cellule étanche de type "sécurité maximale" a été aménagée selon les spécifications contenues dans le "Guide d'implantation et de gestion de lieux d'enfouissement de sols contaminés", afin de recevoir les sols contaminés. Ce type de cellule est hautement sécuritaire puisqu'elle est constituée d'une double membrane synthétique et d'un système de détection et de collecte des fuites. De plus, un programme de contrôle et de suivi du lieu d'enfouissement sera mis en place par le propriétaire de la cellule, c'est-à-dire la ville de LaSalle.

CONCLUSION

La restauration de l'ancien dépotoir de LaSalle représente un cas majeur de décontamination du sol. Les impacts sociaux et les sommes importantes qui furent investis dans cete entreprise nous rappellent avec insistance qu'il est impératif de gérer adéquatement les déchets si l'on veut éviter qu'une telle situation ne se représente dans l'avenir. Je souhaite ardemment que cette conférence vous a sensibilisée sur cet aspect.

RÉFÉRENCES

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INDUSTRIAL SITE DECOMMISSIONING - THE AERIS MODEL

T.L. Bulman, Soil Scientist
Environment Canada, Wastewater Technology Centre

Introduction

Spills, leaks and the improper disposal of raw materials and waste products frequently contaminate soil and groundwater during operations at an industrial site. Once operations cease, the site must be decommissioned in a manner that will render it suitable for future use. Decommissioning is a complex problem because clean-up activities are specific to industry type, products and by-products, the age of the plant, its location (geography, geology, hydrogeology and climate of the site), waste management practices and the proposed future use of the site.

Site decommissioning involves a range of activities, including a detailed assessment of contamination on the site, cleaning and removal of structures on the site, development of a clean-up plan, determination of appropriate contaminant concentrations as clean-up criteria, implementation of the clean-up plan and long term monitoring. The selection of clean-up criteria has been identified as a critical component of site decommissioning by members of the industrial, regulatory and public sectors (Monenco, 1986). The Canadian Council of Resource and Environment Ministers (CCREM) Waste Management Committee has also identified the need to develop a method for setting site-specific clean-up criteria as a high research priority.

A project supported by CCREM to develop a site-specific method for setting clean-up criteria was initiated in 1987 by the National Steering Committee for Industrial Site Decommissioning. The project is being performed by a consortium of consultants headed by Monenco Consultants Ltd. with technical direction from Environment Canada's Wastewater Technology Centre (WTC). The project has received funding from Environment Canada, the U.S. Environmental Protection Agency, the provinces of Alberta, Ontario and Quebec, the Canadian Chemical Producers Association, the Canadian Petroleum Association, the Petroleum Association for Conservation of the Canadian Environment and the Department of Supply and Services Canada. An initial task for CCREM involved a review of current methods for setting clean-up criteria, including technology based criteria (levels acheivable using best available technology), criteria used by other jurisdictions, criteria based on background concentrations and criteria based on risk assessment. It was concluded that the risk assessment approach had the greatest potential for further development and use in a site-specific context. It was recognized that the risk assessment approach is not suitable for all clean-up situations. Risk assessment does have several advantages, however, which satisfy the stated requirements of the the CCREM Waste Management Committee and which make it particularly useful in situations where there is a conflict between the cost of clean-up and protection of the environment. Those advantages include 1) the ability to incorporate site-specific considerations using a scientifically based decision framework and 2) the ability to ensure consistency in the decision making process by placing the decision framework within an "expert system" computer program. The review of methods for setting clean-up criteria has been compiled in a report prepared for the National Steering Committee (Monenco, 1988).

A work plan was developed with two major components: 1) the development of a multi-media (air, water, soil) model for establishing site-specific clean-up criteria using risk assessment and 2) a monitoring program at a field test site for evaluation of transport and fate algorithms in the model. This paper describes progress in the development of the model and provides a brief description of the field validation program.

AERIS Model for Selecting Clean-up Criteria

The product of the multi-media method development is the AERIS model (Aid for Evaluating the Redevelopment of Industrial Sites). Development of the AERIS model has been based on previous work which developed site-specific clean-up guidelines for two decommissioned oil refinery sites in Ontario, Canada (Ibbotson et al, 1987). The original work has been enhanced by incorporating information for various Canadian environments and additional organic and inorganic substances. Much of the information in the AERIS model has been compiled from other sources. Examples include 1) typical chemical and toxicological characteristics of the chemical, 2) characteristics and behavior patterns of the receptor and 3) equations which predict transport of the chemical and estimate the dose from specific exposure pathways. The AERIS model is unique in that this information is integrated into a user friendly "expert system" framework to provide a consistent approach to establishing soil clean-up criteria.

A demonstration version of the model has been developed which links exposure assessment (multi-media pathways models) with toxicity assessment as part of an overall risk evaluation procedure. Continuing work involves assessment of algorithms for detailed estimation of contaminant transport in the soil system, including models currently being developed by the U. S. Environmental Protection Agency (Nofziger et al, 1987; Caupp et al, 1987; Williams et al, 1987). An "expert system" shell is being employed to facilitate the transfer of information between the model user, the model's data base and computational procedures. A flow diagram of AERIS model functions is illustrated in Figure 1.

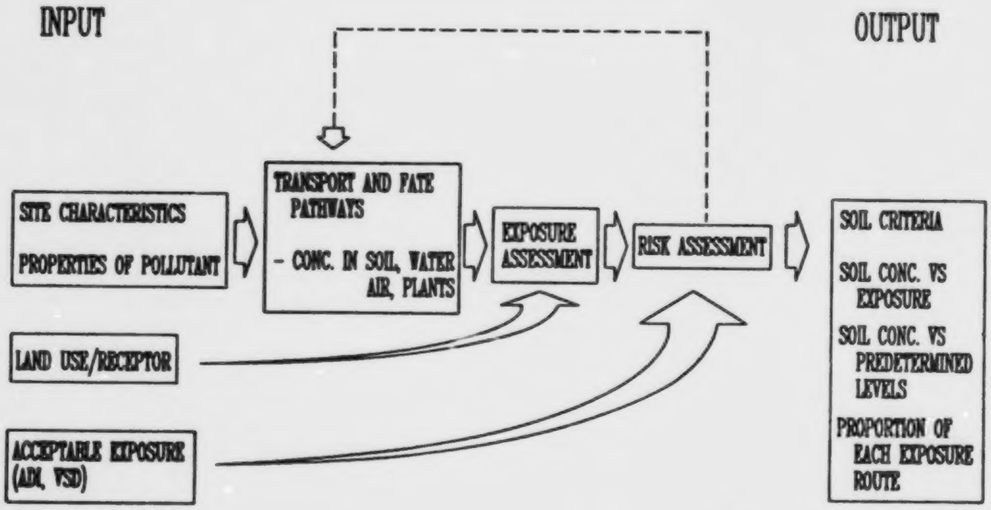

INPUT
OUTPUT
SITE CHARACTERISTICS
PROPERTIES OF POLLUTANT
TRANSPORT AND FATE PATHWAYS
- CONC. IN SOIL, WATER AIR, PLANTS
EXPOSURE ASSESSMENT
RISK ASSESSMENT
LAND USE/RECEPTOR
ACCEPTABLE EXPOSURE (ADI, VSD)
SOIL CRITERIA
SOIL CONC. VS EXPOSURE
SOIL CONC. VS PREDETERMINED LEVELS
PROPORTION OF EACH EXPOSURE ROUTE

FIGURE 1. Flow diagram of a method for selecting clean-up criteria - AERIS model.

Input session. An input session allows the user to enter site-specific data or to rely on default values which are provided from an internal data base. Input questions relate to several categories; the chemical of concern (physical and chemical characteristics), the type of receptor to be studied (adult or child), the proposed land use (residential, agricultural, commercial or recreational) and characteristics of the site's climate, soil and underlying geologic formation. In addition, the user can input exposure levels which produce no adverse effect to the receptor, such as acceptable daily intake (ADI) or virtually safe dose (VSD) and levels predetermined by regulation, such as guidelines for drinking water.

The model searches the internal data base for information which applies to each of the above categories. The user is then presented with three types of input screens: 1) question screens, 2) data edit screens and 3) summary screens. If the required information is not available from the data base, a question screen asks the user for that information in a highly specific format (for example, to identify the porosity of soil on the site). If the user is not able to answer the question, this type of screen allows the user to provide the information in a less specific format, either through acceptance of a default value or selection of some general classification which will provide an estimate of the required information (for example, soil textural class). Explanation screens may also be accessed which identify the type of information required, indicate how it will be used and provide rule-of-thumb information.

When all the required information has been assembled for a category, the user is presented with an edit screen which summarizes the data, including those gleaned from the data base and those contributed by the user. The user is asked to review the data and make changes if appropriate. The revised data is presented in its final form in a summary screen which can be conveniently printed as a record of the model run.

Preprocessing software uses the expert system shell to evaluate information provided by the user (check for completeness, errors and inconsistencies), to provide assistance to the user (explanatory screens) and to control the flow of information to the computational modules.

Fate and transport pathways. The AERIS program calculates the concentrations of a pollutant in soil, water, air and plants and the resulting exposure to a human receptor according to the selected land use.

Several computational modules contain algorithms which evaluate fate and transport pathways. Correlation equations relate movement of a chemical between soil, water and air to physical and chemical properties of the pollutant. Differential flux equations for mass transfer and flow through porous media predict movement of the contaminant in air and water from the zone of contamination to the receptor.

The AERIS model assumes that partitioning of the contaminant between soil, air and water phases has achieved a state of equilibrium prior to site decommissioning. Investigations of equilibrium kinetics at WTC have indicated that virtual equilibrium is generally established within one to two days of introducing a contaminant into soil. Although a true state of equilibrium among phases is never truly achieved in the soil environment, the short period of time required to effect changes in equilibrium is generally insignificant in comparison with the kinetics of other processes. Thus, the equilibrium assumption has been considered acceptable in most situations. The assumption may be unacceptable for use following recent spills or soil disturbances (excavation) in situations where transport kinetics (volatilization, leaching, degradation) are very rapid, i.e. approaching the rate of equilibrium kinetics. Additional studies are being performed at WTC to investigate limitations of the equilibrium assumption.

The ultimate goal of the AERIS model is to relate the concentration of a chemical in the environment to risk to human health. Although the concentration of a chemical on a site may naturally decrease with time (for example, through degradation), the risk to human health may not decrease by a similar proportion. Rather than using a computational procedure to predict decreasing concentrations, and therefore decreasing exposure, with time, the model assumes a constant concentration in soil and uses two indices provided by the user to rank the chemical for a decrease in risk over time, as decribed below in the section on risk assessment. The effects of a decrease in concentration of the chemical over time are thus included as part of the risk assessment process in the AERIS model, rather than being incorporated into the fate and transport processes. The suitability of this approach is currently being reviewed.

Exposure assessment. The dose of contaminant to which the receptor is exposed is calculated using the predicted concentrations of the contaminant in soil, water, air and garden produce and the intake by the receptor of each of these environmental media. The selected land use and receptor provide default values for ingestion or inhalation of environmental media (for example, volume of air breathed, volume of water consumed, proportion of produce consumed which was grown on the site). The default values can be changed by the user, if desired, to create a site-specific scenario. Routes of exposure which are assessed include ingestion of dirt and dust, ingestion of garden produce, ingestion of drinking water and inhalation of vapours and particulate matter. These exposure pathways include distinction between active and passive behaviour, indoors and outdoors, in winter and summer months.

Doses from individual exposure pathways are added together to predict a total dose in units of mg of contaminant per kg of receptor body weight per day.

Risk assessment. Risk assessment is performed by comparing the exposure estimate (total dose to the receptor) with a toxicological criterion (non- toxic or no adverse effect level, such as ADI) from the data base or provided by the user. A linear relationship is assumed between the concentration of the contaminant in soil (C) and the total dose (D) such that the ratio of concentration to dose calculated in the exposure assessment procedure (C_0 and D_0, respectively) is equal to the ratio of "acceptable" concentration (C_a) to "acceptable" dose (toxicological criterion, D_a). The acceptable concentration is thus calculated as:

$$C_a = \frac{D_a\, C_0}{D_0}$$

The AERIS model does not determine the non-toxic or no adverse effect level. This criterion must be obtained upon review of current literature on the chemical, generally requiring the advice of a toxicologist. The AERIS model manipulates the toxicological criterion, however, to estimate an acceptable dose (D_a) which accounts for off-site sources of contaminant and changes in contaminant concentration with time.

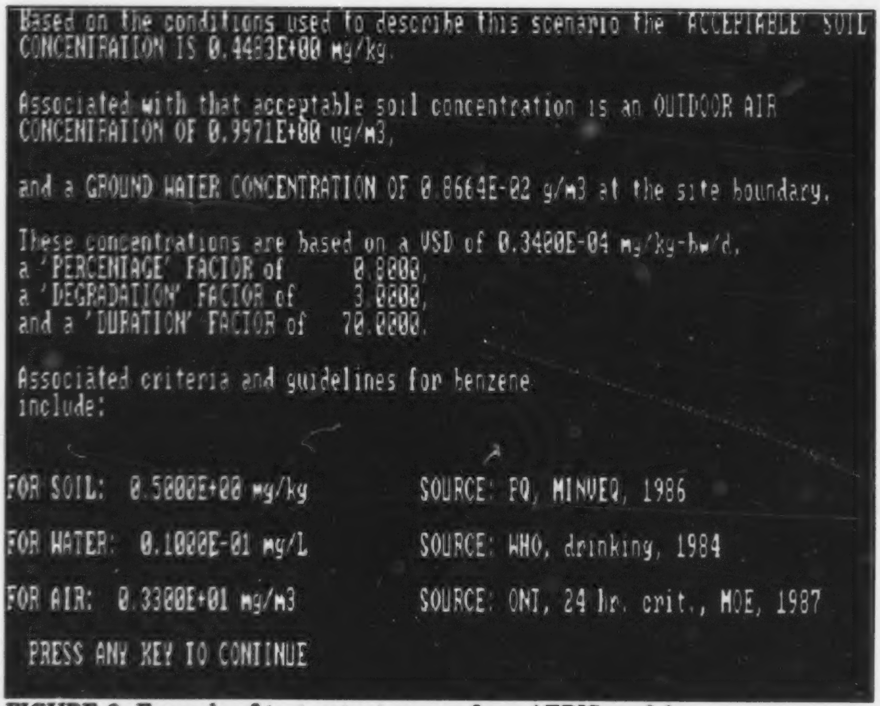
The total dose calculated by the model includes only exposure from sources on the site. Toxicological criteria such as ADI's or VSD's are intended, however, to apply to exposure from all sources in daily life, including off-site sources such as ambient air, purchased food and municipal water sources. As part of the risk assessment process, the user is asked to estimate the percentage of all exposure which results from on- site sources. This percentage is then used to adjust the toxicological criterion so that it applies specifically to on-site sources. For example, if 80% of the dose to a receptor comes from on-site sources, the acceptable exposure to a receptor from on-site sources is 80% of the ADI.

The model incorporates the effect of a decrease in contaminant concentration with time into the risk assessment process, rather than using it in the transport and exposure assessment. It does not, however, use a computational approach to describe the relationship between concentration and adverse (toxic, mutagenic etc.) effect. Instead, the model requires the user to provide two indices. The first index ranks the chemical according to the relationship between concentration and effect. For example, a rank of 1 indicates that a decrease in concentration does not imply a decrease in adverse effect, whereas a rank of 6 indicates that a decrease in concentration implies an equivalent decrease in adverse effect.

The second index ranks the chemical according the length of time the chemical persists on the site (assumed to be equal to 10 degradation half- lives) as compared to the length of time the receptor will live (70 years) or work (50 years) on the site. In this case a rank of 1 indicates the duration of exposure to the chemical is for the entire human lifetime, whereas a high rank indicates the duration of exposure to the chemical is for a small proportion of the human lifetime. Explanation screens are available to assist the user in ranking the contaminant with rule-of-thumb information. High indices for degradation and duration of exposure would result in higher recommended concentrations for clean-up than if degradation of the chemical in soil was not taken into account.

Additional information on the toxicological and risk assessment process has been compiled into a report for the National Steering Committee (CanTox, 1988).

Model output. Output of the AERIS model is provided as text and, through the use of a postprocessor, in graphical form. An example of text output is provided in Figure 2. The output includes a recommended concentration of the contaminant in soil. A comparison of the recommended soil concentration with preclean-up and background concentrations and current regulatory or guideline criteria for soil is also provided. Water, air and plant concentrations which correspond to the recommended soil concentration for site clean-up are provided as well as current regulatory or guideline criteria for each of those media. Comparison of clean-up levels for various media is facilitated using stick diagrams as graphical output, as illustrated in Figure 3. In this way, the recommended criteria can be interpreted quickly within the context of other existing criteria and compliance with other relevant guidelines can be checked.



```
Based on the conditions used to describe this scenario the 'ACCEPTABLE' SOIL
CONCENTRATION IS 0.4483E+00 mg/kg.

Associated with that acceptable soil concentration is an OUTDOOR AIR
CONCENTRATION OF 0.9971E+00 ug/m3,

and a GROUND WATER CONCENTRATION OF 0.8664E-02 g/m3 at the site boundary.

These concentrations are based on a VSD of 0.3400E-04 mg/kg-bw/d,
a 'PERCENTAGE' FACTOR of       0.8000,
a 'DEGRADATION' FACTOR of      3.0000,
and a 'DURATION' FACTOR of    70.0000.

Associated criteria and guidelines for benzene
include:


FOR SOIL:  0.5000E+00 mg/kg          SOURCE: FQ, MINVEQ, 1986

FOR WATER:  0.1000E-01 mg/L          SOURCE: WHO, drinking, 1984

FOR AIR:  0.3300E+01 mg/m3           SOURCE: ONT, 24 hr. crit., MOE, 1987

 PRESS ANY KEY TO CONTINUE
```

FIGURE 2. Example of text output screen from AERIS model

The proportion that each exposure pathway contributes to the overall exposure is also provided. The comparison of exposure pathways is facilitated by the use of pie-charts, as illustrated in Figure 4. Each portion of pie represents the percentage of the total dose predicted to result from the specified pathway. Each general path category (illustrated in the top half of Figure 4) can be further broken down according to the types of human activities (illustrated in the bottom half of Figure 4). This information is useful for developing a clean-up strategy which minimizes risk by reducing the most significant exposure pathway.

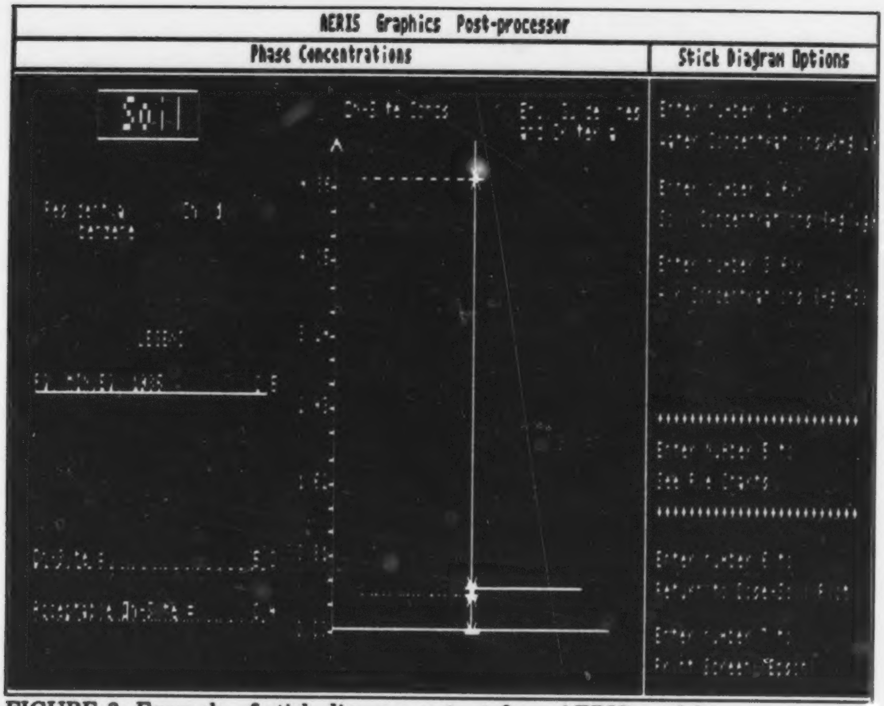


FIGURE 3. Example of stick diagram output from AERIS model

Model Validation

The scope of the current project plan does not include a complete validation of AERIS. Several validation steps, however, are being performed. The model has been calibrated against the risk assessment procedure upon which it was based using the data and recommendations obtained for two decommissioned oil refinery sites. Additional comparisons will be made with independently derived risk-based criteria for other decommissioned sites as such information becomes available. It is not currently planned to perform human exposure surveys for comparison with model predictions, although such information, if available, may be used at a later stage.

Sensitivity of model predictions to variation in input parameters is being assessed. The results of this sensitivity analysis will be reported as part of a user's guide for the model so that the user can determine the precision requirements for model input data.

The one component of the AERIS model which is receiving detailed verification is the component which predicts the transport and fate of the contaminant in the soil environment. A field program was performed to collect data for comparison with model predictions of fate and transport.

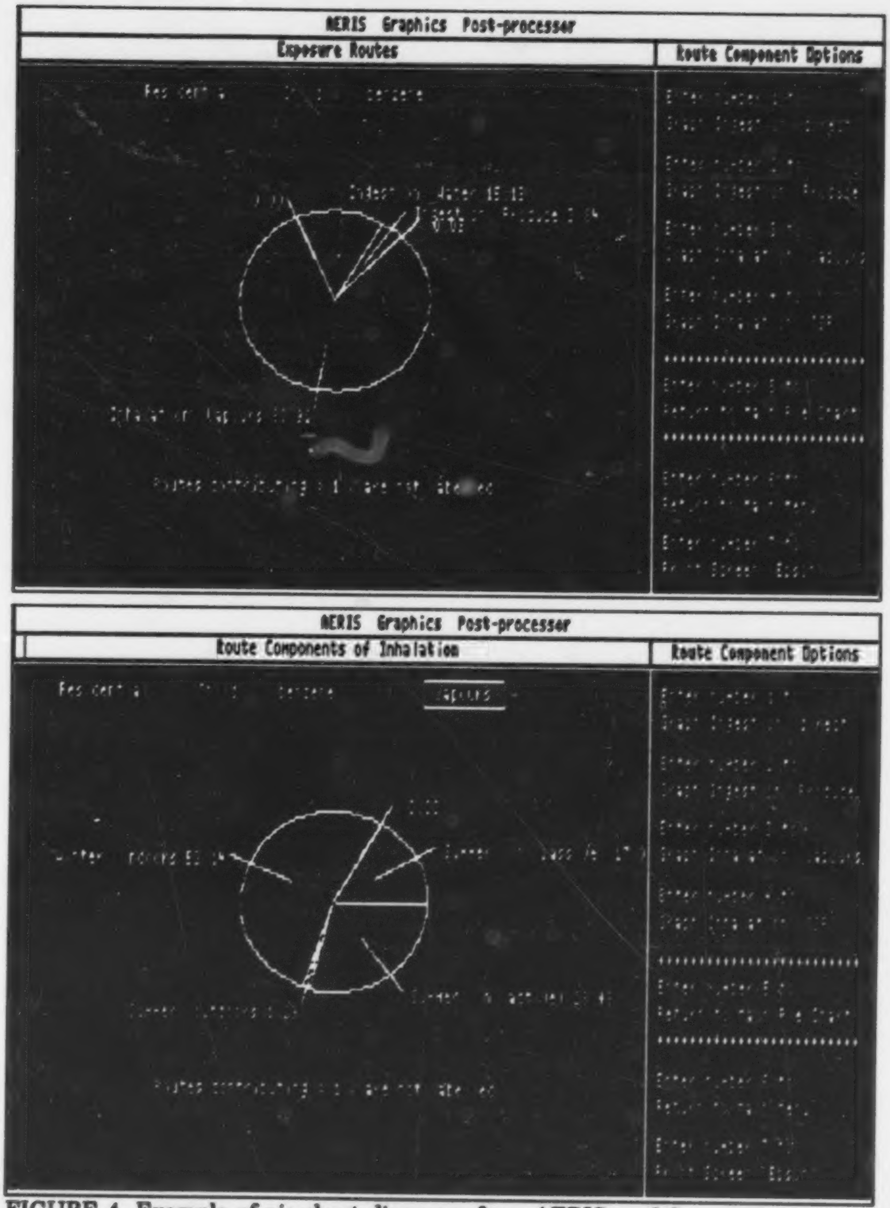

AERIS Graphics Post-processer
Exposure Routes
Route Component Options
AERIS Graphics Post-processer
Route Components of Inhalation
Route Component Options

FIGURE 4. Example of pie-chart diagrams from AERIS model

Field Study for Evaluation of Transport and Fate Algorithms. The field study was designed to evaluate a variety of model algorithms which could be used for environmental pathways analysis, including the fate and transport components of the AERIS model. The objectives of the field program were 1) to acquire site information to use as input parameters for environmental pathways analysis and 2) to collect sufficient information on the concentrations of chemicals in soil, water and air phases over time at the field site to allow comparison with pathways predictions.

A field site was provided by Texaco Canada Ltd. at its petroleum refinery in Nanticoke, Ontario. The field site had been used by Texaco for biodegradation of refinery waste over a period of six years prior to the field study. The site is located on a heavy clay loam of lacustrine origin. Drainage of the site was improved prior to use for waste treatment by installation of tiles at a depth of 75 cm spaced 9 m apart.

Field soil and waste from the refinery were characterized for a range of organic and inorganic constituents and physical and chemical properties. The waste contained 21% oil and grease (wet weight basis), 11% solids and 68% moisture. Based on analysis of the waste by gas chromatography/mass spectrometry (GC/MS), eight chemicals were selected for detailed monitoring including volatile aromatic hydrocarbons (benzene, toluene and para- xylene), polycyclic aromatic hydrocarbons (2-methyl naphthalene, phenanthrene, pyrene, perylene) and total phenols.

Two test plots (9 m x 24 m) were established in a section of the existing biodegradation area with each plot centred over an existing tile drain (illustrated in Figure 5). Each 9 m x 24 m plot was surrounded by a metal barrier protruding 15 cm above the soil surface to prevent movement of runoff water to or from the rest of the biodegradation area. The test plots included a control plot, and a plot receiving waste application to a level of 4% oil in the soil (dry weight basis). Waste was applied to the entire 9 m x 24 m area and incorporated into the soil to a depth of 15 cm by rototilling. Samples were collected from a central core area of 3 m x 18 m to reduce any border effects due to waste application, cultivation and horizontal water migration. Each core area was further subdivided into three 3 m x 6 m sub-plots (blocks) for replication of field measurements.

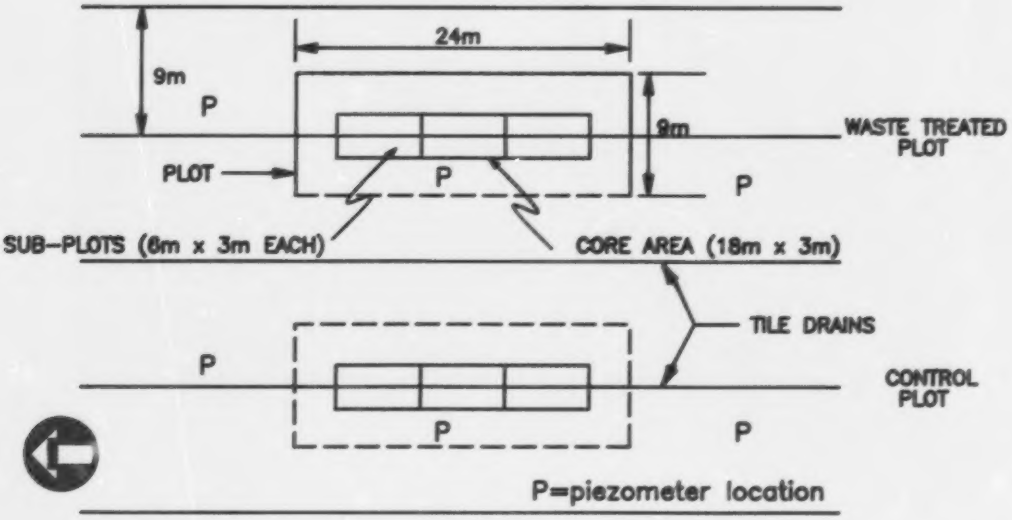


FIGURE 5. Plan of typical test plots at the field site in Nanticoke, Ontario.

The plots were rototilled to homogenize and aerate the soil prior to each sample period. Soil and water sampling were performed every two weeks over the period 7 June to 29 October, 1987 (142 days). Soil samples were collected using a coring device (2 cm diameter) from depths of 0-15 cm, 30-45 cm and 60-75 cm within the core area. At each sampling period new sample locations were selected randomly from a grid. No grid location was sampled on more than one occasion. Following soil sampling, the voids created by taking samples were filled with soil taken from a nearby uncontaminated area. Separate samples were collected for analysis of volatile and semivolatile constituents.

Soil pore water was collected from each sub-plot using porous cup samplers installed at 20 and 40 cm depths and glass brick samplers installed at a 40 cm depth. Since there is a high risk of losing volatile constituents when sampling porous cups due to the use of suction, glass brick samplers were also used because they do not apply suction to the surrounding soil. A glass brick sampler is a hollow glass block, the upper surface of which is perforated and covered with a glass fibre cloth. The glass brick intercepts gravitational water movement as saturated flow or unsaturated flow through macropores (Brown, 1986).

Groundwater was sampled from piezometers which were installed to the north (upgradient), south (downgradient) and within the 9 m x 24 m boundary of each plot. Samples were also collected from the tile drain beneath each plot. To ensure adequate soil moisture for the collection of water samples, the test plots were irrigated with approximately 15 cm of water every two weeks.

The frequency and procedure for sampling were the same for control and waste treated plots, with all samples being archived at 4°C prior to analysis. Precision and accuracy of the analytical methods used for each type of sample were checked through the use of method blanks, internal standards and addition of deuterated surrogate chemicals to 10% of the samples.

Transport and Fate Pathways Evaluation Input parameters were determined through soil and waste characterization, as well as measurement of volatilization and degradation kinetics observed at the field site and phase partitioning coefficients measured in the laboratory. Algorithms are currently being evaluated for prediction of transport and fate pathways by running the model with average input parameter values, as well as with average values plus and minus one standard deviation. Predicted concentrations in soil, with time and depth, are being compared with observations and the sensitivity of model predictions to several input parameters is being evaluated.

Current Status of the AERIS Model

Currently the AERIS model predicts contaminant concentrations in air, water, soil and plants and exposure to a human receptor using algorithms based on previous work (Ibbotson et al, 1987) within an expert system framework. The data base contains information for seven chemicals; benzene, phenanthrene, pyrene, methyl ethyl ketone, lead, zinc and selenium. This version of the model is available for demonstration.

Use of an expert system framework provides a consistent approach to making decisions for setting criteria on a site-specific basis. It also facilitates the process of updating the AERIS model, as modules can be changed or replaced as our understanding and modelling of transport, exposure and risk improve. It is anticipated that the fully developed AERIS model will be updated on a regular basis.

Improvements which are currently being considered for the AERIS model include an expansion of the data base, incorporation of the option to select a risk assessment end point other than human toxicology (such as water quality guidelines, toxicity to fish) and stepwise calculation of concentration, exposure and risk with time.

The AERIS model will be beneficial not only as an aid in setting clean-up criteria, but also in the site assessment process and in development of a clean-up strategy. A major benefit to be derived from the use of the AERIS model is the ability to evaluate the site for many different scenarios, including different land uses and a variety of receptor characteristics. This capability should provide useful information in considering the approach to clean-up and reuse of the site. Sensitivity analysis of model input parameters will also identify the most important site characteristics which should be evaluated as part of the site investigation process.

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Perth Services Ltd.
Winnipeg, Manitoba

James S. Johnson

Paper unavailable at time of printing

RELIABILITY OF SAMPLING AND ANALYTICAL PROTOCOL FOR ASH SAMPLING

Environmental Affairs
Ogden Martin Sytems Inc.

David Sussman

Paper unavailable at time of printing

THE NATIONAL INCINERATOR TESTING AND EVALUATION PROGRAM: CHARACTERIZATION OF RESIDUES FROM A MASS BURNING INCINERATOR

by S.E. Sawell and T.W. Constable

Environment Canada, Environmental Protection,
Wastewater Technology Centre, Burlington, Ontario

For presentation at 10th Canadian Waste Management Conference
Winnipeg, Manitoba, October 1988.

INTRODUCTION

In 1984, Environment Canada established the National Incinerator Testing and Evaluation Program (NITEP) to assess the impact of municipal solid waste (MSW) incinerator emissions on the environment. As a part of NITEP, the Wastewater Technology Centre has conducted laboratory tests to determine the chemical and leaching properties of residues generated from different Canadian MSW incinerators. To date, residues from a modular or two-stage combustion design incinerator with no air pollution control, a lime-based air pollution control pilot plant and a mass burning incinerator with electrostatic precipitator (ESP) air pollution control, have been characterized. This paper describes the results from the third study in the series, which examined three different types of ash (bottom, boiler/economizer and ESP), collected under five different operating conditions, from the Quebec Urban Community (QUC) EFW facility.

Quebec Urban Community Incinerator Facility

The QUC facility consists of four parallel mass burning incinerator units, each designed to handle a total of about 200 tonnes of refuse per day. A cross section schematic of the facility is shown in Figure 1. Refuse is fed onto the incinerator bed and is transported through the incineration chamber via vibrating grates. Flue gas passes up through the waterwalled boiler/economizer heat recovery chambers and enters the electrostatic precipitator air pollution control unit before discharging through the stack to the atmosphere.

In the spring of 1986, one of the units was modified to increase operating efficiency and reduce stack emissions. The modifications included removing a waterwall arch from above the burning grate and construction of a series of new "bull noses" to enhance the mixing of the flue gases. In addition, new under-fire and over-fire air systems were installed to facilitate better combustion in the incineration chamber. Schematics of the original and modified designs are given in Figure 2.

Six sets of samples (bottom ash, boiler/economizer ash and ESP fly ash) were collected for testing from the modified incinerator under five different operating conditions during performance testing (PT). Two of these operating conditions, PT's 4 and 14, were considered "poor". The remaining four, PT's 2, 5, 7 and 9, were

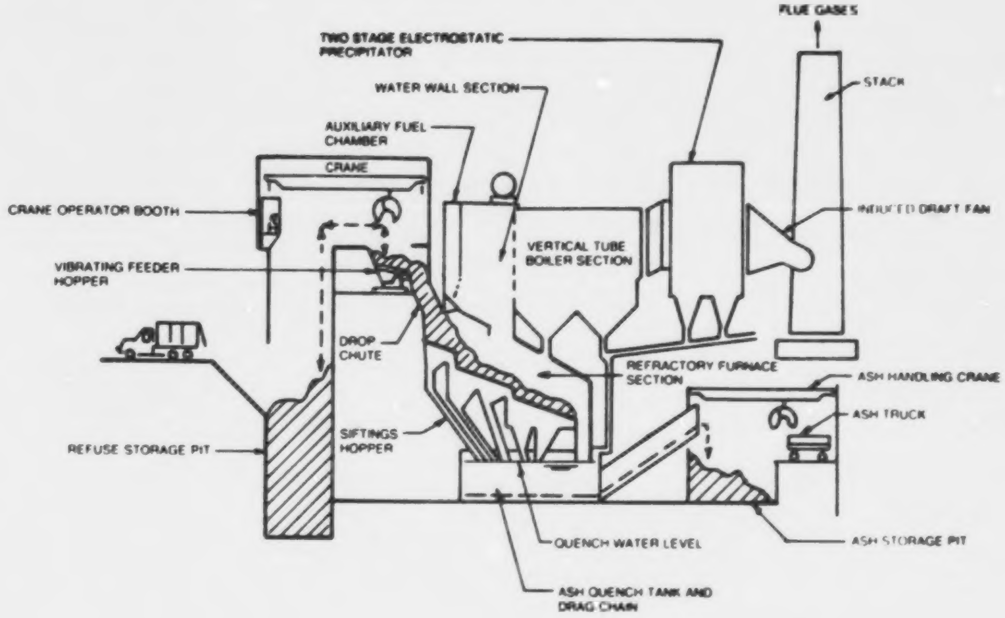
FLUE GASES
TWO STAGE ELECTROSTATIC PRECIPITATOR
STACK
WATER WALL SECTION
AUXILIARY FUEL CHAMBER
CRANE
CRANE OPERATOR BOOTH
INDUCED DRAFT FAN
VERTICAL TUBE BOILER SECTION
VIBRATING FEEDER HOPPER
DROP CHUTE
REFRACTORY FURNACE SECTION
ASH HANDLING CRANE
ASH TRUCK
SIFTINGS HOPPER
REFUSE STORAGE PIT
QUENCH WATER LEVEL
ASH STORAGE PIT
ASH QUENCH TANK AND DRAG CHAIN

FIGURE 1: QUEBEC INCINERATOR SEQUENTIAL CROSS-SECTION

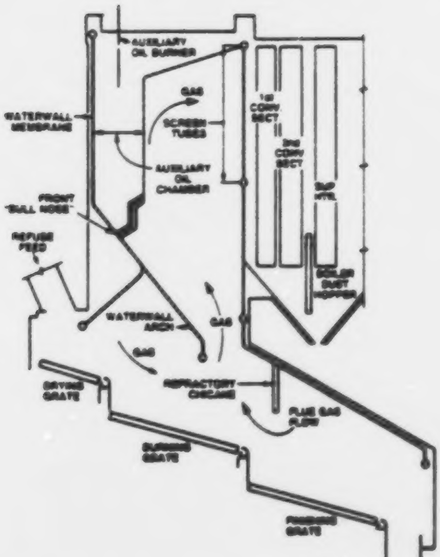
AUXILIARY OIL BURNER
GAS
WATERWALL MEMBRANE
SCREEN TUBES
1st CONV. SECT
2nd CONV SECT
AUXILIARY OIL CHAMBER
FRONT "BULL NOSE"
REFUSE FEED
BOILER DUST HOPPER
WATERWALL ARCH
GAS
GAS
DRYING GRATE
REFRACTORY CHICANE
FLUE GAS FLOW
BURNING GRATE
FINISHING GRATE

FIGURE 2a: ORIGINAL QUC INCINERATOR DESIGN

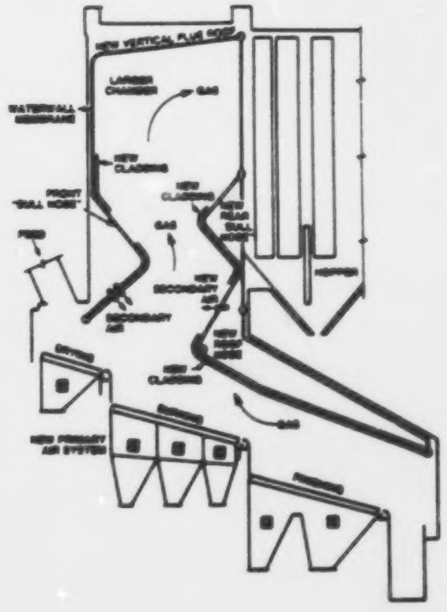
NEW VERTICAL FLUE ROOF
LARGER CHAMBER
GAS
WATERWALL MEMBRANE
NEW CLADDING
FRONT "BULL NOSE"
NEW CLADDING
NEW REAR BULL NOSE
GAS
FEED
HOPPER
NEW SECONDARY AIR
SECONDARY AIR
NEW CLADDING
DRYING
BURNING
GAS
NEW PRIMARY AIR SYSTEM
FINISHING

FIGURE 2b: MODIFIED QUC INCINERATOR DESIGN

considered "good" operating conditions. A summary of the different operating conditions is given in Table 1.

Table 1. Performance Test Operating Conditions

Parameters	Performance Test # PT2	PT4	PT5	PT7	PT9	PT14
Overall Condition	Good	Poor	Good	Good	Good	Poor
Design Temp. (°C)	865	850	1000	1030	1030	975
Design Refuse Load (T/h)	20	28	28	32	32	28
Excess Air (%)	140	130	80	90	90	115
CO Concentration in the Stack (ppm)	Low 24	80	28	55	55	High 165

Samples of bottom ash were collected directly off the finishing grate, just prior to the quench tank, with the use of a specially designed grab sampling device. The grab samples were composited for each test period, then coned and quartered several times. The sample was then crushed down to a particle size no larger than 9.5 mm. Material which was too hard to be reduced below 9.5 mm in size, was separated and catalogued as reject material. The concentrations of contaminants in the bottom ash reported here are for processed samples. Boiler/economizer and ESP fly ash samples were collected directly from the respective ash hoppers.

EXPERIMENTAL AND ANALYTICAL PROCEDURES

The organic contaminants measured in the ash and leachate samples were total polychlorinated dibenzo-p-dioxins (PCDD), polychlorinated dibenzofurans (PCDF), polychlorinated biphenyls (PCB), polychlorinated aromatic hydrocarbons (PAH), chlorinated benzenes (CB) and chlorinated phenols (CP). The samples were extracted and analyzed at Environment Canada's River Road Environmental Technology Centre. These methods are described in detail in the NITEP Methodology report (Environment Canada, 1988).

The ash and leachate samples were analyzed at the Wastewater Technology Centre laboratories for boron, cadmium, chromium, cobalt, copper, nickel, lead and zinc. The ash samples were digested using aqua regia/hydrofluoric acid and peroxide. The metals in the ash and the leachates were measured using either directly coupled argon plasma spectroscopy (DCAP), flame atomic absorption (AA) or AA with graphite furnace. Leachate samples were also analyzed for chlorides and sulphates.

The ashes were subjected to a batch leach test with distilled water, at a liquid-to-solid ratio of 20:1 (Constable and Cote, 1986). The test was performed in duplicate and involved slowly rotating a "proofed" glass container, containing a 50 g ash sample and 1 litre of distilled water, for 18 hours. After the mixing period, the mixture was coarse filtered through 0.8 - 1.0 micron pore size glass fibre filters. Duplicate leachates were then composited to provide a sufficient volume for analytical purposes. The leachate samples were then stored at 4°C prior to extraction and analyses.

The ashes were also subjected to ASTM Draft Method No. 34.02-01123, the Sequential Batch Leaching Procedure (SBLP). The procedure is similar to the batch leach test with the exception that, after each mixing period, the liquid and solid phases were separated via pressure filtration through a 0.45 um membrane filter. The remaining solids were then re-exposed to fresh distilled water at the same liquid-to-solid ratio. The procedure was repeated for 5 cycles. The tests were performed in duplicate and the leachate samples were analyzed for pH and total dissolved solids. A sub- sample of each leachate was then preserved with concentrated nitric acid and analyzed for metals. Separate unpreserved sub- samples were analyzed for sulphates and chlorides.

In addition, the ashes were subjected to the Sequential Chemical Extraction (SCE) procedure (Fraser and Lum, 1983). The SCE is a stepwise separation of the total concentration of a metal into five distinct fractions. A summary of the SCE is given in Table 2.

Table 2. Summary of the Sequential Chemical Extraction Procedure

Fraction	Digestion Method
Fraction A	1 M LiCl/CsCl in 60% CH_3OH
Fraction B	1 M CH_3COONa with Acetic Acid
Fraction C	1 M NH_2OH + HCl in 25 % Acetic Acid
Fraction D	Nitric Acid with Peroxide, Heat + CH_3OONH_4 in 20% Nitric Acid
Fraction E	Aqua regia/HF with peroxide + HCl

RESULTS AND DISCUSSION

Organic Contaminants

The average concentrations of each of the major groups of organic contaminants are summarized in Table 3. All concentrations given are recovery corrected on a per sample basis.

With the exception of PAH, concentrations of organic contaminants increased from bottom ash through to ESP fly ash. This trend of higher organic concentrations on the finer ash particles has been noted in many previous studies (for example, Hartlen and Elander, 1986; Vogg et al., 1987; Sawell et al., 1987; NUS, 1987). Most of these organic contaminants present in refuse are either destroyed, altered or volatilized in the incineration chamber and carried over in the flue gas. The smaller particle size of the fly ash provides a greater surface area to volume ratio, resulting in greater sorption of the organic compounds. Since the PAH group of organic compounds is typically more stable and less volatile than the other compounds measured here, the higher PAH concentrations in bottom ash were not unexpected (NUS 1987).

Table 3. Average Organic Contaminant Concentrations in the Ashes

Ash Type	PCDD	PCDF	PCB	PAH	CB	CP
Bottom	0.03	ND	ND	390	5.3	14
Boiler/ Economizer	58.6	43.2	ND	72	52	125
ESP	720	245	5.8	240	1510	2300

All units are ng/g (dry weight). ND = not detected.

The average organic contaminant concentrations in the leachates from the batch leach test are presented in Table 4. Due to the very low solubility of dioxins, furans and PCB's in water, these compounds were not detected in the leachates. However, trace levels of CB and PAH compounds, which are also considered insoluble in water, were detected in the leachates. It is speculated that because of their high affinity for small particulates, that these compounds were present bound to ultra-fine particles which remained suspended in the leachates after filtration.

Table 4. Average Organic Contaminant Concentrations in the Leachates

Ash Type	PCDD	PCDF	PCB	PAH	CB	CP
Bottom	ND	ND	ND	0.09	0.01	0.14
Boiler/Economizer	ND	ND	ND	0.02	0.03	0.24
ESP	ND	ND	ND	0.01	0.02	0.14

All units are ug/L. ND = not detected.

Inorganic Contaminants

The total metal concentrations in the ashes are given in Table 5. The ashes contained low to moderate concentrations (less than 2000 ppm) of boron, cadmium, cobalt, chromium, copper and nickel (with the exception of Cu in PT7 bottom ash sample) and high to very high concentrations of lead and zinc (up to 70000 ppm), especially in the boiler/economizer and ESP fly ashes.

The distribution of metals amoung the three types of ash is dependent upon the relative volatility of the metal concerned. Typically, the more volatile metals, such as cadmium, lead and zinc, were found in much higher concentrations in the ESP ash, while the less volatile metals such as chromium, cobalt, and nickel were measured in higher concentrations in the bottom ash. These results are consistent with the elemental classification of metals in coal fly ash (Klein et al., 1975) and results from previous studies (Vogg et al., 1986; Schneider, 1986; Sawell et al., 1988).

The concentrations of cadmium, lead and zinc in the ESP ashes appear to be affected by the incinerator operating conditions. Lower concentrations of these metals were measured in the ashes generated under "poor" operating conditions than those generated under "good" conditions. This is probably largely due to dilution caused by the greater quantities of material carried over to the ESP unit during the

TABLE 5 TOTAL METAL CONCENTRATIONS IN THE ASHES

ASH TYPE	Run Number	METALS							
		B	Cd	Co	Cr	Cu	Ni	Pb	Zn
Bottom Ash	PT2 (Good)	182	7.50	284	993	1580	600	1000	1600
	PT5 (Good)	135	6.30	238	1110	850	1370	6000	2000
	PT7 (Good)	38	<2.00	213	1270	26000	974	1200	3200
	PT9 (Good)	170	7.50	266	1200	1970	1050	1100	1300
	PT4 (Poor)	218	6.40	478	1180	928	1060	1600	2400
	PT14 (Poor)	185	7.00	215	984	1400	1080	1500	1400
Boiler/ Economizer Ash	PT2 (Good)	120	346	153	600	896	318	16000	22000
	PT5 (Good)	72	254	144	720	540	360	9600	20000
	PT7 (Good)	83	179	165	630	471	330	8000	18000
	PT9 (Good)	220	162	110	850	490	420	7100	15000
	PT4 (Poor)	75	116	150	776	600	705	5000	9200
	PT14 (Poor)	164	168	146	627	576	444	9200	12000
ESP Ash	PT2 (Good)	168	959	54	741	1430	168	21000	70000
	PT5 (Good)	294	1080	63	750	1350	142	26000	60000
	PT7 (Good)	187	729	77	807	1260	230	24000	45000
	PT9 (Good)	250	682	75	762	1020	189	17000	35000
	PT4 (Poor)	144	480	72	843	1050	240	11000	30000
	PT14 (Poor)	178	405	87	546	843	185	11000	25000

All units are in ug/g (dry weight).

"poor" condition runs Environment Canada, 1988). Since the concentration of copper in the PT7 bottom ash sample was 20 times higher than the average concentration of the remaining samples, this value was considered an outlier. The large difference was probably due to a piece of elemental copper being present in the sub-sample of ash.

Variations in the average pH of the leachates from the Sequential Batch Leaching Procedure (SBLP) are shown in Figure 3. The leachate pH in the SBLP is established by the pH of the ash. The bottom and boiler/economizer ashes generated leachates which were highly alkaline throughout the 5 cycle test. However, the ESP ashes collected under the "good" and "poor" operating conditions generated leachates with significantly different pH levels during the first 2 cycles of the SBLP. Leachates from the ESP ashes generated under the "good" operating conditions were mildly acidic (about pH 6.5) during the first 2 cycles, then increased dramatically to above pH 9.6 during the remaining cycles. Those generated under the "poor" conditions were highly alkaline throughout the 5 cycles.

The SBLP was also used to determine the potential inorganic contaminant mobility in water over a wide range of liquid-to- solid ratios (20:1 to 100:1). The average cumulative fraction leached results (after 5 cycles) are given in Table 6. Cumulative fraction leached is defined as the ratio of the summed mass of a contaminant measured in the leachates to the mass of that contaminant in the orginal sample, expressed as a percentage. The total dissolved solids (TDS) results indicate that the ESP ash was the most soluble of the three ash types. Almost 40% of the ESP ash, 25% of the boiler/economizer ash and about 4% of the bottom ash were solubilized over the five cycles of the SBLP. Most dissolution of the ashes (over 75% of that observed) occurred during the first cycle of the leach test. Similarly, a greater percentage of the metals in the ESP ash were solubilized than in the other two ashes. Approximately 80% of the boron, 65% of the cadmium, 20% of the zinc, 2.5 % of the cobalt and 1.2% of the nickel were leached from the ESP ashes. Only 30% of the boron, almost none of the zinc and none of the cadmium, cobalt and nickel were leached from the boiler/economizer and bottom ash samples during the SBLP.

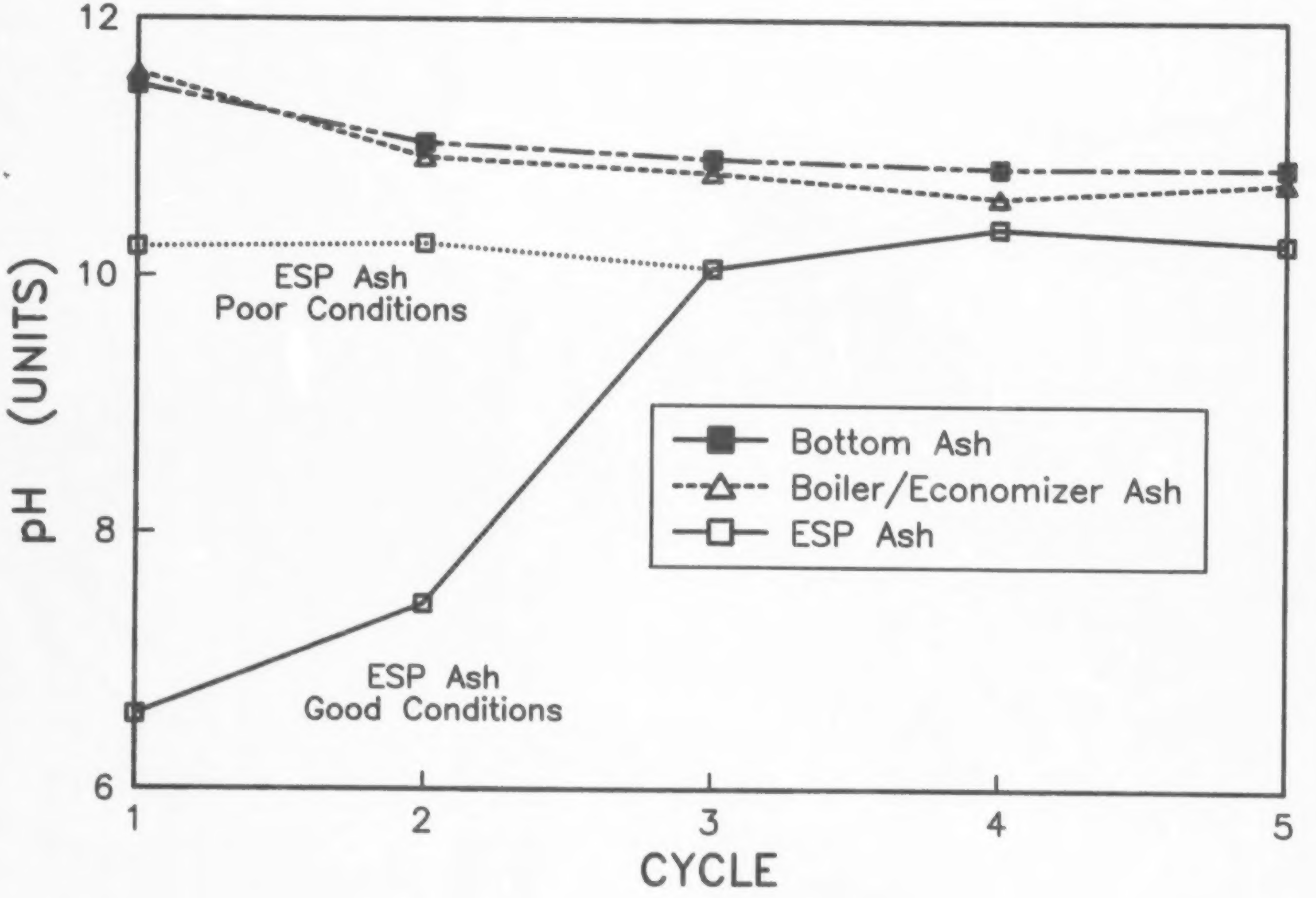

FIGURE 3: Average Leachate pH Readings

Table 6. Average Cumulative Fraction Leached Results (%)

Parameter	Ash Type Bottom	 Boiler/Economizer	 ESP
TDS	3.9	25.7	39.1
Boron	9.9	28.9	80.9
Cadmium	0.0	0.0	67.1
Chromium	0.2	0.7	0.6
Cobalt	0.0	0.0	2.5
Copper	0.2	0.7	0.3
Lead	0.5	8.5	1.2
Nickel	0.0	0.0	1.3
Zinc	0.2	0.3	19.2

The solubility of the cadmium and zinc in the six ESP ashes was found to be dependent on the pH of the leachate. In Figure 4 the fractions of cadmium and zinc leached from the ashes during the first cycle of the SBLP are plotted against leachate pH. As noted earlier, the pH of the initial leachates from the ESP ashes collected under the "good" operating conditions were mildly acidic. This enhanced the solubility of cadmium and zinc, whereas the alkaline pH of the "poor" condition ash leachates resulted in limited solubility.

The results from the SBLP were also used to determine the total chloride concentration in each ash. Since chlorides dissociate readily in water, even under alkaline conditions, it was assumed that 100% of the chloride in the ashes was solubilized during the 5 cycles of the SBLP. Therefore, the total chloride concentration in each ash was considered equal to the cumulative release of chloride after 5 cycles. The ESP ashes contained almost 20 times the concentrations of chloride than did the bottom ashes. In comparison, the boiler/economizer ashes contained only twice the concentrations measured in the bottom ash.

Chloride concentrations in the six ESP ash samples varied widely. The average chloride concentration in the ashes from runs PT2, PT5 and

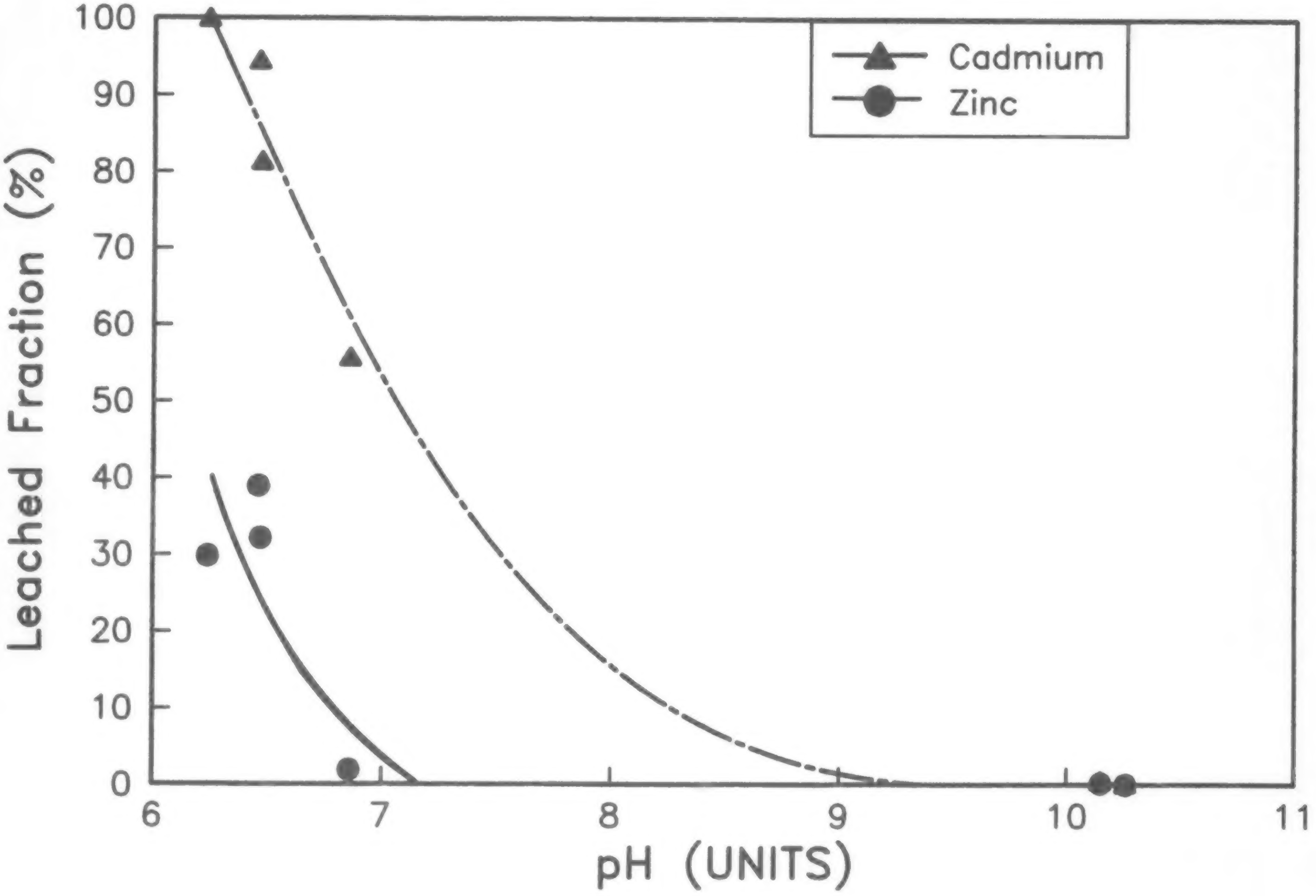

FIGURE 4: Effect of pH on the Solubility of Cadmium and Zinc in ESP Ash

PT7 was 21600 ppm, which was almost twice the amount found in the PT4, PT9 and PT14 ash samples. These variations may be due in part to variations in flue gas temperatures in the ESP unit during the six test runs. It was observed that the chloride concentrations in the ESP ashes were higher at lower ESP outlet temperatures (Figure 5). With the exception of PT9, the lower temperatures in the ESP unit were associated with the "good" operating conditions while the higher temperatures were associated with the "poor" conditions. The high temperature recorded for PT9 was probably influenced by the load rate of 32 tonnes per hour.

The Sequential Chemical Extraction (SCE) procedure was used to estimate the potential leachability of the metals in the ashes over the life of a landfill. The descriptions and interpretations associated with each of the five fractions are summarized in Table 7. It is important to note that the results from this test are not indicative of expected leachate quality under the conditions suggested and that the interpretations are assumed generalities.

Table 7. Summary of the Sequential Chemical Extraction Procedure Descriptions and Interpretations

Fraction	Description	Interpretation
A	Ion exchangeable	Immediately available for leaching
B	Surface oxide and carbonate bound ions	Potentially available for leaching under acidic conditions
C	Iron and manganese bound metal ions	Potentially available for leaching under reducing conditions
D	Sulphide and organic matter bound ions	Unavailable for leaching under normal leaching conditions
E	Residual metal ions	Unavailable for leaching

For illustration purposes, the SCE analyses for cadmium, copper, lead and zinc are shown in Figure 6. In general, the results of the SCE verify the results from the SBLP, in that metals in the bottom ash were found to be less leachable than those in the boiler/economizer

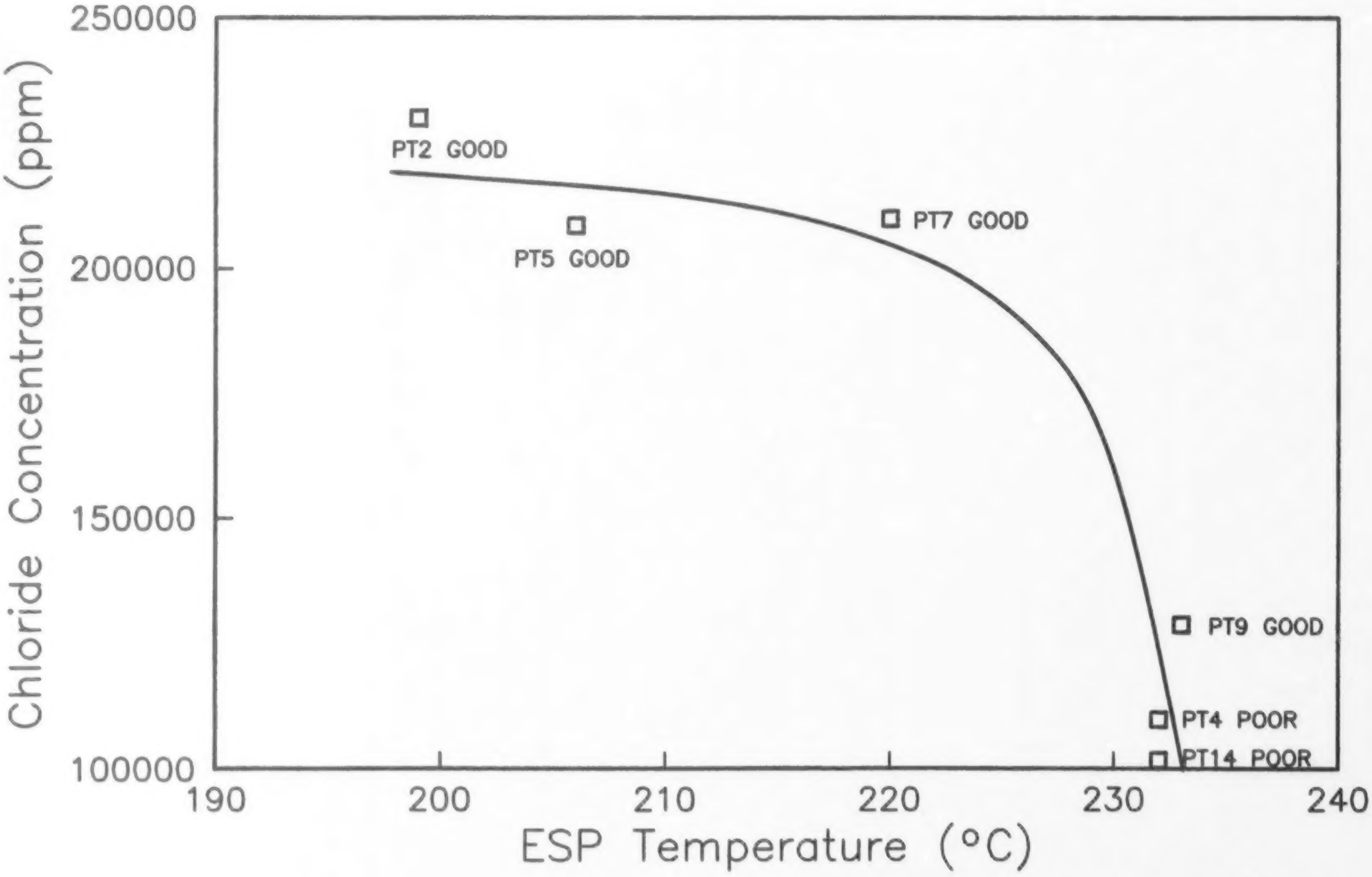

FIGURE 5: ESP Outlet Temperatures Versus
Chloride Concentrations in ESP Ashes

were found to be less leachable than those in the boiler/economizer ashes, which in turn were less leachable than those in the ESP ashes. About 25% of the copper, and 50% of the lead and zinc in the bottom ash is potentially available for leaching over the life of a landfill. In contrast, almost 50% of the copper, and over 65% of the cadmium, lead and zinc in the boiler/economizer fly ash is available for leaching. Over 70% of the same metals were estimated to be available for leaching from the ESP ash under the same conditions. These results are similar to results obtained by Wadge and Hutton (1987).

Metal Speciation and Leachability

The results from this study indicate leachability of metals from MSW incinerator ashes is highly dependent on the pH of the leaching environment, the relative particle size of the ash and the speciation of the metals. The low leachable fraction results for the bottom ash was due, in part, to the relatively large particle size and the alkaline pH of the ash. The results also suggest that the metals in the bottom ash were mostly speciated as relatively insoluble silicates and oxides. The higher leachability of the boiler/economizer ashes was the result of the smaller particle size of the ash and the increased presence of more soluble compounds, such as sulphates and chlorides. The even greater leachability of the ESP ash was probably due to the lower pH of the ashes (except those collected under the "poor" conditions), the finer size of ash particles and the presence of readily soluble compounds, such as chloride salts.

The results also suggest that the ESP ash consists of an alkaline core made up of the less volatile and less leachable metals, such as copper and chromium. This alkaline core is coated with a readily soluble surface layer of acid gas products and metals, such as cadmium, lead and zinc, which condense out of the flue gas forming a layer of metal salts.

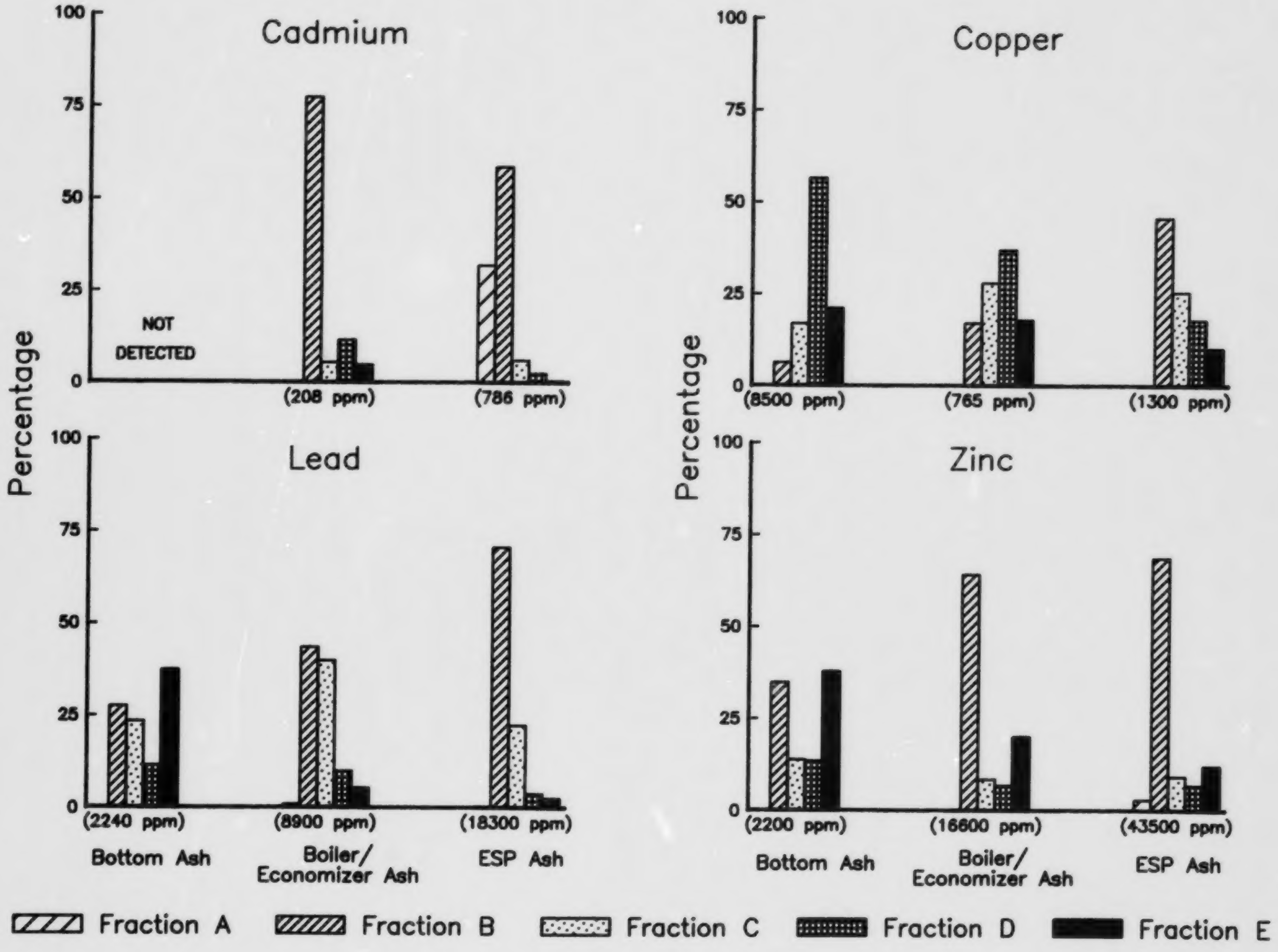

FIGURE 6: Results From the Sequential Chemical Extraction Analyses

CONCLUSIONS

With the exception of PAH's, the total concentrations of organic compounds in the ESP ash were one to two orders of magnitude greater than those in the boiler/economizer ash, which in turn were one order of magnitude greater than those in the bottom ash. This distribution trend indicates that sorption of organic contaminants increases as the ash particle size decreases.

Results from the batch leach test indicate that dioxins, furans and PCB's were non-leachable in water. Since chlorophenols are partially soluble in water the presence of low levels in the leachates was expected. However, trace quantities of chlorobenzenes and PAH's, which are considered insoluble in water, were also detected in the leachates. It is speculated that these compounds were strongly sorbed onto very fine particulates which remained in suspension in the leachate after filtration.

All ashes contained relatively low to moderate concentrations (less than 2000 ppm) of boron, cadmium, cobalt, chromium, copper and nickel. Relatively low concentrations of lead and zinc were also measured in the bottom ashes, however, very high concentrations of lead and zinc (up to 26000 ppm of Pb and 70000 ppm of Zn) were present in the boiler/economizer and ESP fly ashes. The distribution trend indicates that fly ashes contained higher concentrations of the more volatile metals such as cadmium, lead and zinc, which condense out of the flue gas, than does the bottom ash.

The results from the Sequential Batch Leach Procedure indicate that bottom ashes are relatively insoluble in water. Only about 4% of the bottom ash dissolved during the five cycles of the test. Conversely, fly ashes were much more soluble, in that, about 25% of the boiler/economizer ash and almost 40% of the ESP ash were solubilized during the SBLP. Typically, less than 1% of the chromium, cobalt, copper, lead and zinc, and less than 10% of the boron present in the bottom ash were leached during the SBLP. This limited solubility was attributed to the alkaline pH and the relatively large particle size of the ash. However, the SCE analyses indicate that a large fraction of many of the metals may potentially be available for leaching under the reducing conditions of an older landfill. It may be appropriate to limit metal solubility by disposing of this material in a segregated area of a landfill (monofill), where alkaline leaching conditions would prevail for a much longer period of time than in a co- disposal landfill.

Results from both the SBLP and the SCE analyses indicate that substantial fractions of the boron, cadmium, cobalt, copper, lead, nickel and zinc in both types of fly ash are available for leaching over the life of a landfill. The high leachability of these ashes was attributed to the small particle size of the ash and the presence of readily soluble metal salts. These results would appear to warrant the treatment of the fly ash residues prior to disposal. To facilitate treatment of these residues, it is suggested that fly ash be collected separately from bottom ash.

In general, the results from this study indicate that the chemical and leaching properties of the ESP ash are affected by the different operating conditions. The ash generated under the "poor" operating conditions contained lower concentrations of cadmium, lead and zinc, and were slightly less leachable than those generated under the "good" conditions. While this appears to favour the use of the "poor" operating conditions, it must be noted that the "poor" conditions also resulted in less efficient incinerator operation, significantly higher emission levels of contaminants, and generated greater quantities of ash which still require proper disposal (Environment Canada, 1988). Therefore, it is clear that in terms of human health and the environment, efficient incinerator operating conditions should be favoured over "poor" conditions, thus enhancing air pollution control and reducing quantities of ash requiring handling and disposal.

Acknowledgement

The professional and analytical support of the Laboratory Services Section of the Wastewater Technology Centre and the River Road Environmental Technology Centre is gratefully acknowledged. The technical assistance of T. Barthelette and D. Creaser is also gratefully acknowledged.

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HUDSON COUNTY, NEW JERSEY ASH RESIDUE/BYPASS LANDFILL DESIGN

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SCS Engineers

INTRODUCTION

In 1985, Hudson County developed and the New Jersey Department of Environmental Protection (NJDEP) approved a solid waste management plan designed to address the disposal of all wastes generated within the County. The solid waste management plan includes a mandatory recycling program, a municipal solid waste incinerator (MSWI), and an ash residue/bypass landfill. The Hudson County Improvement Authority (HCIA) proposes to construct the MSWI and the landfill at site referred to as the Koppers Company Seaboard Site, next to the Belleview Turnpike in Kearny, New Jersey.

The HCIA is responsible for the solid waste management plan and its implementation. The vendor for the MSWI is Ogden-Martin. The landfill principally will serve as a repository for ash residue from the MSWI, for bypass wastes when the MSWI is not operational, and for residues from the County's planned recycling centers. The purpose of this paper is to present the design alternatives considered for the ash/bypass landfill, the resultant final design, and results of ash and leachate testing conducted during the initial landfill permitting process.

SITE BACKGROUND

The site selected for the MSWI and ash/bypass landfill is unique in many respects. The Koppers Company operated a large chemical processing facility at the Seaboard site from the early 1900's to the mid-1970's, after which the facility was dismantled. The facility processed coal gas, coal tar, creosote, cyanide, and other chemicals. The industrial activities left the site's surface and subsurface soils and groundwater significantly contaminated. The site currently is the subject of a remedial investigation and feasibility study and cleanup under the supervision of the NJDEP. The extent of the contamination has been documented in reports prepared by Koppers' consultants.[1,2,3] The siting of the MSWI and landfill facilities will complement the planned site remediation and make beneficial use out of a relatively unusable site.

The South Kearny area, where the proposed project site is located, is predominantly a heavy industrial area with large tracts of vacant land. The Public Service Electric and Gas Power Plant is located in close proximity to the site, directly to the east across the Hackensack River. Two other industrial/chemical facilities are located to the west of the site. The closest residential area is approximately 0.8 meters (m) to the southeast of the site in Jersey City, New Jersey.

The entire Koppers site is approximately 60.7 hectacres (ha). Approximately 36.4 ha will be used for the MSWI access road and adjoining wetlands, and 24.3 ha for the landfill. The landfill is to be located on the eastern half of the site. The MSWI will be located directly west of the landfill, to provide easy access to the facility for ash disposal. The Hackensack River borders the site to the north and east. A railroad embankment borders the site to the south.

The site generally is flat with a man-made berm of miscellaneous fill abutting the Hackensack River along portions of the north section of the property. As shown on the geologic cross section, Figure 1, the site is underlain by man-made fill, a peat and organic-clayey slit layer, discontinuous sand and clayey silt layers, varved clay of varying depths, and glacial till.The following major stratigraphic features were determined to impact the development of the site as a landfill:

- The fill zone (i.e., the upper 3 m to 4 m of man-placed fill) is contaminated as a result of previous site use.
- The foundations from the Koppers plant have been left in-place and consist of reinforced concrete mats, slabs, and grade beams, which are supported by timber piles. The timber piles appear to reach the till layer at depths of 20 m to 23 m.
- Varved clay is a layer of cohesive, compressible soil beneath the site. The varved clay deposits have low strength when subjected to horizontal shearing. In certain areas, especially in the eastern two-thirds of the site, the varved clay has been eroded and replaced by an alluvial deposit of soft, compressible organic clay/silt, with intermittent sand layers.

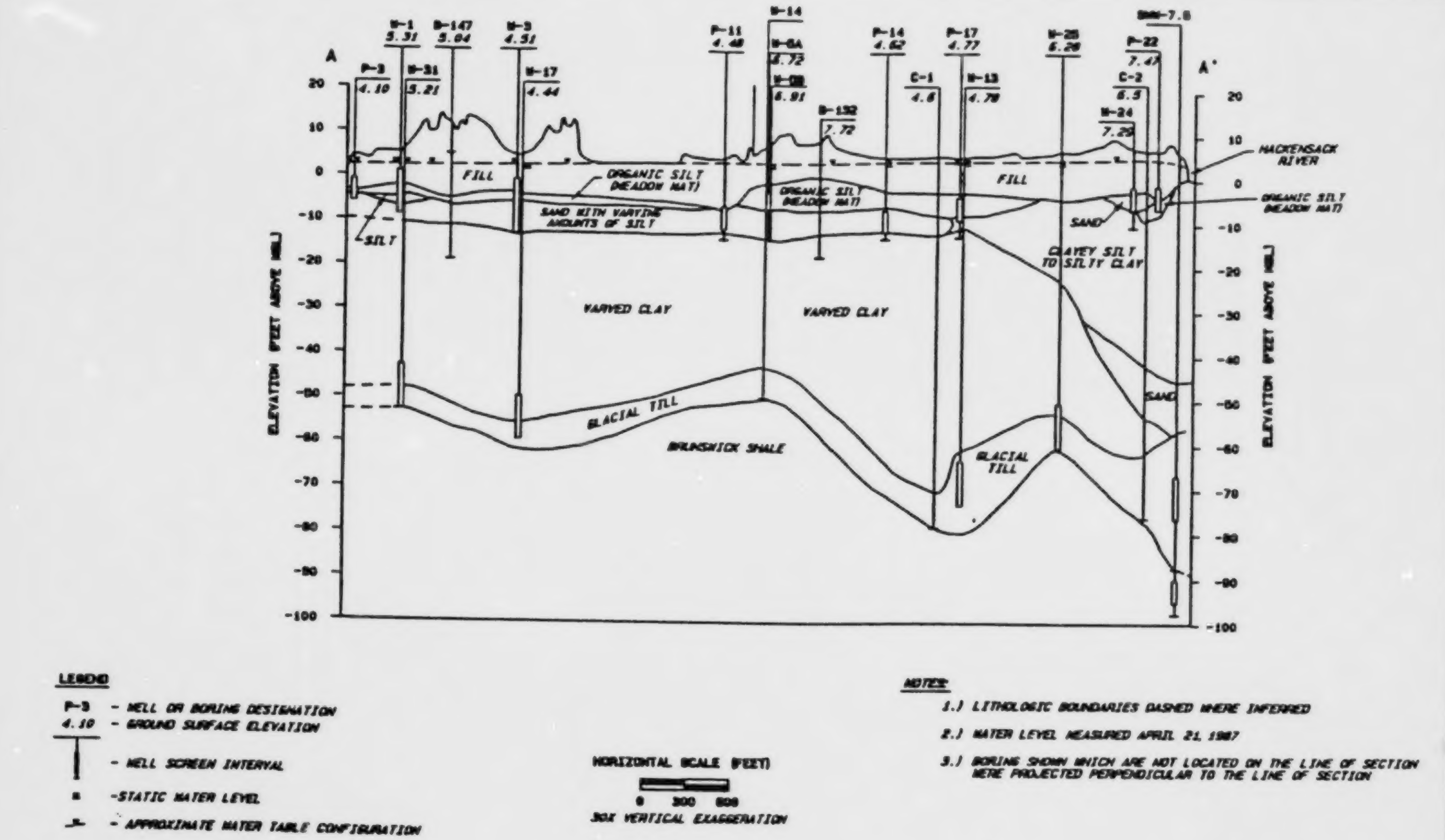
SOLID WASTE QUANTITIES

Figure 2 presents the projected waste-flow diagram for Hudson County assuming the MSWI and recycling center facilities are operational.[4] The primary waste to be disposed of in the landfill will be the ash residues from the MSWI. The landfill also will receive residues from the proposed County material recovery facilities and bypass waste.

Table 1 presents an estimate of the average daily quantities of wastes which will require disposal in the landfill, including their estimated in-place densities and landfill volumes consumed. The estimated quantity of bypass waste is based on data provided by Ogden-Martin. The ash residue should comprise approximately two-thirds of the landfill volume, and the quantities should be fairly consistent from day to day and from week to week. However, the volume of recycling residuals received on a daily basis may vary significantly. In general, bypass waste will be received only when one or more of the furnaces in the MSWI is shut down from routine maintenance or operational problems. During those limited times, part or all of the 1,089 metric tons per day (Mg/day) wastestream may be bypassed to the landfill. The HCIA is considering the option of excavating this bypass material and returning it to the MSWI for processing.

PHYSICAL CHARACTERISTICS OF ASH RESIDUE

As a part of this project, laboratory tests were conducted on samples of combined ash residue from a MSWI plant in Marion County, Oregon. This facility was designed and constructed by Ogden-Martin, and is similar to the facility being designed for Hudson County.


A
A'
P-3 4.10
W-1 5.31
W-31 5.21
B-147 5.04
W-3 4.51
W-17 4.44
P-11 4.48
W-14
W-6A 3.72
W-6B 6.91
B-132 7.72
P-14 4.62
C-1 4.8
P-17 4.77
W-13 4.78
W-25 6.28
W-24 7.29
C-2 6.5
P-22 7.47
BM-7.8
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
ELEVATION (FEET ABOVE MSL)
FILL
SILT
ORGANIC SILT (MEADOW MAT)
SAND WITH VARYING AMOUNTS OF SILT
VARVED CLAY
GLACIAL TILL
BRUNSWICK SHALE
CLAYEY SILT TO SILTY CLAY
SAND
HACKENSACK RIVER
LEGEND
P-3 - WELL OR BORING DESIGNATION
4.10 - GROUND SURFACE ELEVATION
- WELL SCREEN INTERVAL
-STATIC WATER LEVEL
- APPROXIMATE WATER TABLE CONFIGURATION
HORIZONTAL SCALE (FEET)
0 300 600
30X VERTICAL EXAGGERATION
NOTES:
1.) LITHOLOGIC BOUNDARIES DASHED WHERE INFERRED
2.) WATER LEVEL MEASURED APRIL 21, 1987
3.) BORING SHOWN WHICH ARE NOT LOCATED ON THE LINE OF SECTION WERE PROJECTED PERPENDICULAR TO THE LINE OF SECTION

THIS CROSS-SECTION DEPICTS GEOLOGIC CONDITIONS AT SPECIFIC LOCATIONS SHOWN BASED ON SITE INVESTIGATIONS. GEOLOGIC CONDITIONS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE SITES.

Source: Keystone, August 1987.

FIGURE 1. GEOLOGIC CROSS-SECTION

Based on Phase II Waste Characterization Results, May 18, 1987

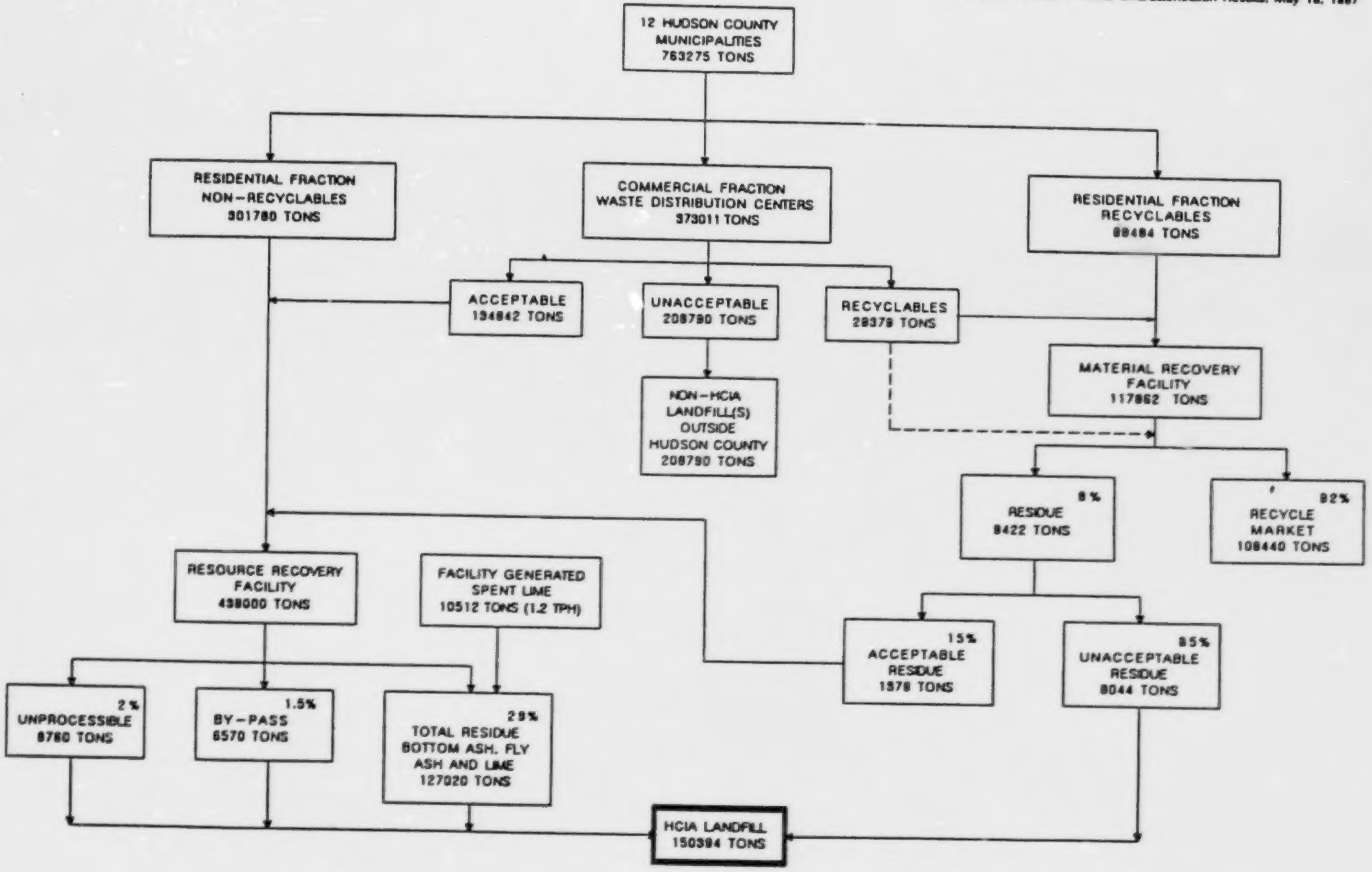

12 HUDSON COUNTY MUNICIPALITIES 763275 TONS
RESIDENTIAL FRACTION NON-RECYCLABLES 301780 TONS
COMMERCIAL FRACTION WASTE DISTRIBUTION CENTERS 373011 TONS
RESIDENTIAL FRACTION RECYCLABLES 88484 TONS
ACCEPTABLE 134842 TONS
UNACCEPTABLE 208790 TONS
RECYCLABLES 28379 TONS
NON-HCIA LANDFILL(S) OUTSIDE HUDSON COUNTY 208790 TONS
MATERIAL RECOVERY FACILITY 117862 TONS
8% RESIDUE 9422 TONS
92% RECYCLE MARKET 108440 TONS
RESOURCE RECOVERY FACILITY 438000 TONS
FACILITY GENERATED SPENT LIME 10512 TONS (1.2 TPH)
15% ACCEPTABLE RESIDUE 1378 TONS
85% UNACCEPTABLE RESIDUE 8044 TONS
2% UNPROCESSIBLE 8760 TONS
1.5% BY-PASS 6570 TONS
29% TOTAL RESIDUE BOTTOM ASH, FLY ASH AND LIME 127020 TONS
HCIA LANDFILL 150394 TONS

FIGURE 2. HUDSON COUNTY IMPROVEMENT AUTHORITY ANNUAL SOLID WASTE FLOW

TABLE 1

ASSUMED DISPOSAL RATES
HUDSON COUNTY ASH/RESIDUE LANDFILL

Ash Residue

- Refure to RRF = 438,000 tons/year
  = 1,200 tons/day
- 70 to 75 percent weight reduction, 71 percent assumed
- Weight of Ash = (0.29) (1,200 tons/day) = 348 tons/day
- Assumed in-place density = 115 lbs/cubic foot
- Volume of ash = $\frac{\text{(348 tons/day) (2,000 lbs/ton)}}{\text{3,105 lbs/cy}}$ = 220 cubic yards/day

Bypass

- Projected bypass = 6,570 tons/year
  = 18 tons/day
- Assumed in-place density = 1,200 lbs per cubic yard
- Volume of bypass = $\frac{\text{(18 tons/day) (2,000 lbs/ton)}}{\text{1,200 lbs/cy}}$ = 30 cubic yards/day

Unprocessibles & Unacceptable Residues

- Unprocessibles = 8,760 tons/year = 24 tons/day
- Unacceptable Residue = 8,044 tons/year = 22 tons/day
  Total = 46 tons/day
- Assumed in-place density = 1,200 lbs per cubic yard
- Volume = $\frac{\text{(46 tons/day) (2,000 lbs/ton)}}{\text{1,200 lbs/cy}}$ = 77 cubic yards/day
  say 80 cubic yards/day

Total Daily In-Place Volume = 330 cubic yards/day

The following tests were conducted to determine the physical properties of the ash:

- Specific gravity
- Grain size analysis
- Minimum index density
- Consolidated undrained triaxial compression test
- Moisture density relationship

The tests were conducted to determine the possible in-place densities as a function of the degree of compaction and the strength characteristics of the ash, including shear strength and angle of internal friction. The relationship of the in-place density to the level of compactive effort is important in determining the effective life of the landfill. The strength parameters are important in assessing the stability of the landfill mass.

The test results on the ash residue indicated the following:

- Maximum dry density: approximately 2,150 kg per cubic meter
- Specific gravity: 2.78 to 2.86
- Angle of internal friction: 43.8 to 46.5 degrees
- Cohesion intercept (average)
  - @ 88 percent maximum dry density: 42,135 Pascals (Pa)
  - @ 95 percent maximum dry density: 68,942 Pa
- Hydraulic conductivity:
  - @ 88 percent maximum dry density: 2.22×10^{-3} cm/sec
  - @ 95 percent maximum dry density: 1.31×10^{-4} cm/sec

A maximum ash residue density of 1,850 kg per cubic meter was chosen to estimate the in-place density of the ash. This represents 85 percent of the maximum dry density. This value was chosen because the fill will not be constructed like a controlled earthen embankment, which requires substantial monitoring to insure that the in phase density is achieved. Given the granular nature of the ash residue, the 85 percent compaction effort should be achieved with nominal compactive effort. The normal landfill operation of spreading and compacting the material in 0.3 to 0.6-meter intervals should achieve the target in-place density. Occasional field testing will be conducted to verify the in-place density.

An in-place density of 712 kg per cubic meter is assumed for bypass and other residual wastes which will be disposed of in the landfill. The in-place density of refuse can vary widely depending on the equipment used to compact the refuse, operational practices, height of lifts, and depth of the landfill.

CHEMICAL CHARACTERISTICS OF ASH RESIDUE AND LEACHATE

Historically, MSWI ash has been codisposed with raw refuse rather than in dedicated monofills, where only ash is disposed. Information concerning the leachate characteristics from ashfills is thus limited. However, data from Saugus, Massachusetts, Chicago, Illinois, and Pinellas County, Florida facilities which operate MSWI and U.S. EPA sponsored studies indicate that leachate from ashfills is relatively high in pH and contains metals concentrations below applicable regulatory standards.[5,6,7]

Cundari[8] has completed studies for Westchester County, New York on leachate characteristics from an ash monofill. Table 2 presents the

TABLE 2

CHARACTERISTICS OF LEACHATE FROM ASHFILLS VERSUS SANITARY LANDFILLS VERSUS DOMESTIC WASTEWATER

Leachate Parameter	Pilot Test Ashfill Leachate** Range of Values*	Typical+ Sanitary Landfill Leachate	Typical Untreated Domestic Wastewater++
pH	10.2 - 10.6	4.8 - 7.5	
TDS	3,100 - 16,000	1,000 - 10,000	250 - 850
TSS	2 - 30	100 - 400	100 - 350
Alkalinity, as $CaCO_3$	60 - 180	500 - 6,000	50 - 200
BOD	30 - 250	2,000 - 15,000	110 - 400
COD	100 - 500	5,000 - 40,000	250 - 1,000
TOC	25 - 150	1,000 - 10,000	80 - 290
Aluminum	0.4 - 1.5	---	
Arsenic	<0.005	<0.003 - 0.03	
Barium	<0.2	ND - 1.1	
Cadmium	0.01 - 0.05	<0.05 - 0.1	
Chromium, total	<0.01 - 0.12	ND - 0.08	
Copper	0.25 - 0.64	ND - 9.0	
Iron	0.04 - 0.10	10 - 1,000	
Lead	<0.05 - 0.18	0.02 - 1.0	
Magnesium	0.08 - 1.53	100 - 500	
Manganese	<0.01 - 0.02	0.1 - 50	
Mercury	<0.0005	---	
Nickel	0.06 - 0.14	0.01 - 0.8	
Selenium	<0.005 - 0.009	---	
Zinc	0.006 - 0.031	0.5 - 135	
Calcium	87 - 105	60 - 2,500	
Chloride	165 - 5,100	100 - 2,400	
Potassium	70 - 835	50 - 1,000	
Sodium	155 - 3,350	100 - 4,000	
Sulfate	1,750 - 4,300	25 - 500	

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* mg/l, except pH.

** Kenneth L. Cundari and Dr. Jeffrey M. Laurie, "Ashfills and Leachate," Waste Age, November 1986, pp 82-86.

+ Compilation of data from following:

1. Chian and de Walle, "Sanitary Landfill Leachates and Their Treatment," 1 ASCE, April 1986.
2. Thornton and Blane, "Leachate Treatment By Coagulation and Precipitation," JASCE, August 1973.
3. Boyle and Ham, "Biological Treatability of landfill Leachate," JWPCF, Vol. 46, No. 5, May 1974.

++ Metcalf & Eddy, Inc., Wastewater Engineering, McGraw-Hill, New York, New York, Second Edition, 1979, p. 64.

Westchester County study results compared to typical sanitary landfill leachate and domestic wastewater. The following conclusions can be made from Cundari's research:

- The pH of the ashfill leachate is consistently higher than neutral. Sanitary landfill leachate generally is acidic as the result of anaerobic decomposition in landfill.
- The leachate is fairly well buffered and comparable to many neutral waters.
- The regulated metals concentrations are low.
- The organic fraction of the leachate is biodegradable (i.e., ratio of COD/BOD is low) and comparable in strength to domestic sewage.
- The salt concentrations are high and comparable to sanitary landfill leachate.

The Westchester MSWI uses electrostatic precipitors, while the plant proposed for Hudson County will likely use dry scrubbers for acid gas removal. The use of dry scrubbers will increase the amount of lime in the ash residue. The increased lime concentrations may have the following impacts on the leachate:

- Potentially increase the pH of the leachate
- Improve the buffering capacity of the leachate and restrict the solubilization of heavy metals.

In December 1986, Ogden Martin conducted EP toxicity and ash leaching tests on ash from a facility similar to that proposed for Hudson County The EP toxicity and TCLP results are presented in Table 3. Two of eighteen samples exceeded the EP toxicity limits for lead. However, the average lead concentrations for the eighteen samples were below the regulatory limit. All the samples tested using the TCLP were below the proposed regulatory limits. Of note, the results of the above EP Toxicity tests likely overestimate the concentrations of metals due to the low pHs utilized in the testing procedure.

The ash leaching test results are shown in Table 4. The test involved filling a cylinder with ash and allowing deionized water to filter through it. The leachate was collected and analyzed for heavy metals in accordance with 40 CFR Part 261. The concentrations of all regulated metals in the leachate were below the EP toxicity limits. Although these results do not simulate all the conditions which could occur in the field, it gives a sense of the probable worst case concentrations of metals which could be expected in the leachate.

LANDFILL DESIGN

Given the limited area available to develop a landfill at the site, alternative landfill designs were developed and evaluated with the objective of maximizing the available fill volume (i.e., landfill life) and minimizing the site development costs, while still achieving the regulatory performance standards. The design alternatives were evaluated based on the provisions of the New Jersey Administrative Code (NJAC) 7:26.2. The State's solid waste regulations specify design, performance, and operational standards for landfills. The regulations allow for deviations from the design standards as long as the performance standards are achieved.

TABLE 3

SUMMARY OF ASH LEACHATE CHARACTERISTICS

	EP Toxicity Results		Regulatory EP Toxicity Limits**	TCLP Results		Proposed[+] TCLP Regulatory Limit
	Range	Avg.		Range	Avg.	
Arsenic	<0.05	<0.05	5.0	<0.050	<0.050	5.0
Barium	0.109 - 0.217	0.185	100	0.169 - 0.370	0.270	100
Cadmium	0.09 - 0.43	0.24	1.0	<0.010 - 0.050	0.012	1.0
Chromium	0.03 - 0.07	0.05	5.0	<0.010	<0.010	5.0
Lead	0.56 - 21[++]	3.51	5.0	0.001 - 2.98	<0.850	5.0
Mercury	<0.05	<0.05	0.2	<0.010	<0.010	0.2
Selenium	<0.05	<0.05	1.0	<0.050	<0.050	5.0
Silver						
Alkalinity				147 - 740	447	
Chloride				150 - 462	274	
Fluoride				209 - 611	485	
Hardness				0.10 - 1.37	1.05	
Magnesium				375 - 984	653	
Nitrate				<0.001 - 0.405	<0.023	
Sulfate				<0.100 - 0.200	<0.153	
Calcium				245 - 571	348	

* All values in mg/l.

** U.S. EPA SW-846, "Test Methods for the Evaluation of Solid Wastes: Physical/Chemical Methods.

+ Proposed rules found in Federal Register, June 13, 1986, Vol. 51, No. 114.

++ Two out of 18 samples exceeded EP Toxicity limits.

TABLE 4

ASH LEACHING TEST RESULTS

Leachate Parameters	Leachate** (mg/l)	Regulatory EP Toxicity Limit (mg/l)
Arsenic	< 0.02	5
Lead	1.61	5
Barium	34.3	100
Mercury	< 0.02	0.2
Cadmium	0.67	1
Selenium	< 0.009	1
Chromium	0.14	5
Silver	0.06	5

* Ash (bottom ash/fly ash combined) taken from Marion County, Oregon Resource Recovery Facility (by Ogden-Martin).

** Feed solution to leaching column was deionized water.

The following variables were considered in the development of the alternative landfill design:

- Setback and buffer distances
- Bottom liner configuration and types
- Exterior slope angle (not discussed in detail in this paper)
- Subgrade improvements
- Remedial work by Koppers

These variables were selected because of the impact that each has on the size, configuration, and cost of the landfill.

Setback and Buffer Requirements

The setback distance from the property line is a crucial variable in determining the ultimate landfill volume that is available at the site. Four alternative setback distances were considered. The first two alternatives evaluated the setback distances specified in NJAC 7:26-2A.5. The last two alternatives considered variable setback distances based on the unique features of the site and facility requirements. Where the site borders the Hackensack River to the north and east, the setback distances were measured from the water's edge rather than the property line, because the property line extends into the Hackensack River. The regulations state that the setback distances should be measured from the property boundaries, which would be to the County's advantage, since it could create additional landfill volume. However, the water's edge was chosen as a practical physical boundary from which to measure the setback distance.

The alternative setback distances which were considered are summarized below:

- 91-meter setback distance (Alternative A): A 91-meter setback distance from the toe of the slope of the landfill to the property line is required in areas where the groundwater flow velocity is equal to or greater than 0.3 m per day (NJAC 7:26-2A.5). This is a worst case scenario because the velocity of the groundwater is expected to be less than 0.3 m per day. The area available for landfilling is limited for this alternative to approximately 8.5 ha, and the maximum potential fill elevation is only 22.9 m NGVD. The area between the landfill and the property lines (i.e., waters edge) was calculated to be greater than the footprint area of the landfill.
- 46-meter setback distance (Alternative B): A setback distance of 46 meters may be permitted in areas where the groundwater flow velocity is less than 0.3 m per day, and the facility will comply with the State's landfill performance standards. The landfill footprint conforming to the 46-meter setback, was approximately 13.8 ha.
- Variable setback distances (Alternatives C and D): The purpose of the regulatory setback distances is to provide ample time to conduct remedial measures in the event of a liner failure, which could result in the release of leachate to the groundwater, and to provide space for environmental monitoring, access roads, landscaping, and other landfill related facilities. The site is unique in that remedial measures to manage contaminated groundwater are anticipated as a part of the remedial strategy for

clean-up of the site, thus providing protection against the future release of ground-water contaminants. In addition, the landfill is surrounded on the north and east by the Hackensack River, by a railroad embankment to the south, and to the west by the proposed MSWI.

As such, in order to maximize the area available for landfilling, two alternative conceptual designs with variable setback distances were evaluated. The major difference between the two alternatives is the location of the access road. With Alternative C, the access road is located between the flood control dike and the landfill. With Alternative D, the access road is constructed on top of the flood control dike, which reduces the setback distance on the northern side of the landfill.

Alternative D, which is illustrated by Figure 3, was selected for the following reasons:

- Provides the maximum landfill capacity and sufficient space for access roads, monitoring, and drainage controls.
- Exceeds the performance standards for the setback distances specified in the regulations.
- In all cases, the minimum 15 m buffer distance is maintained.
- No direct impact on adjoining properties will result from the proposed alternative compared to the specified regulatory setback distance.
- It is assumed that a slurry trench cutoff wall and groundwater control system will be installed around the perimeter of the site as a part of Koppers' site remediation. This system will provide equivalent or greater impedance to groundwater flow than the soil mass required by the setback requirements.

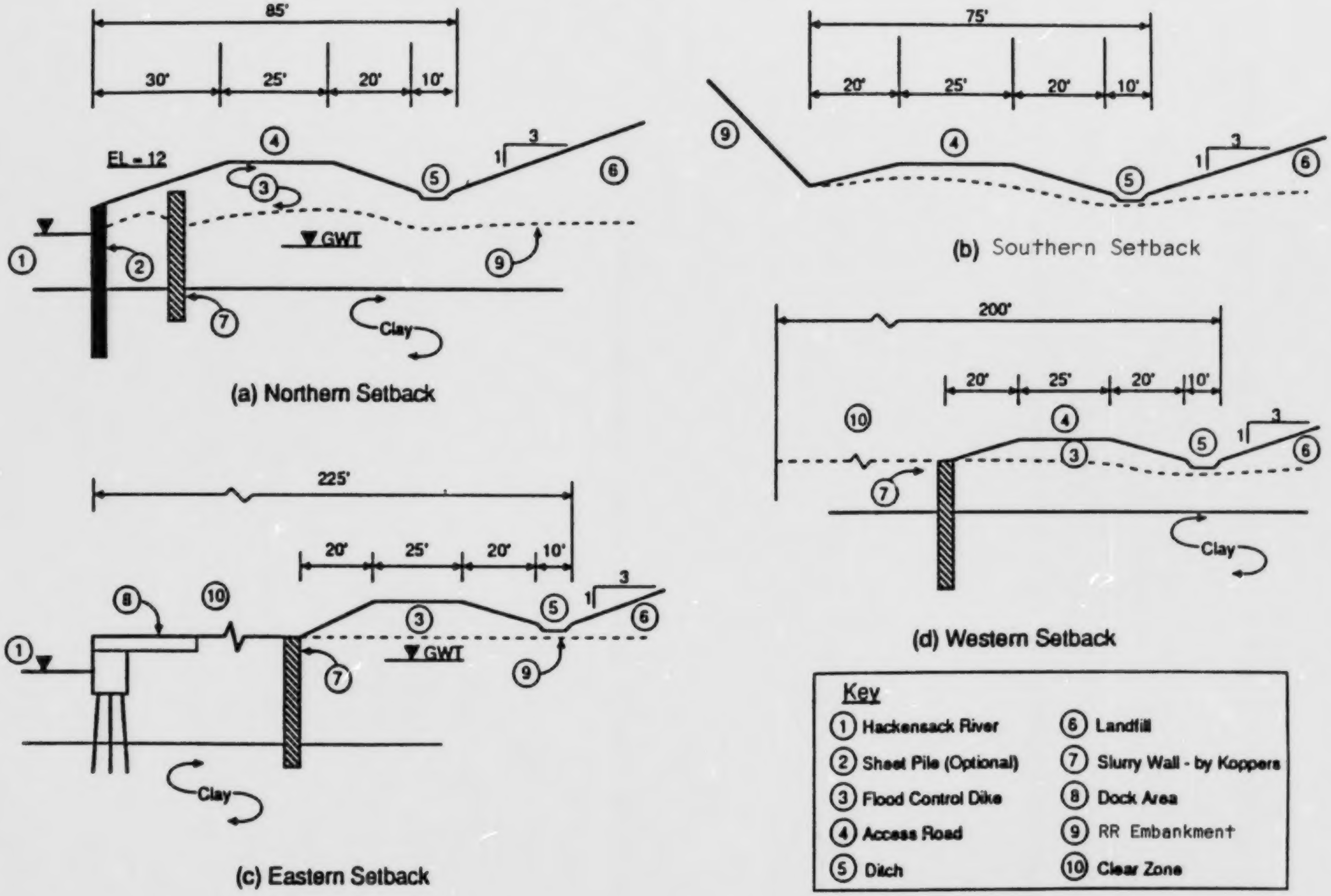
Liner Design

The thickness of the liner components was evaluated to determine the optimum design configuration. A design criteria of "no excavation" was established because of the potential health and safety impacts from subsurface construction activities and the presence of a high groundwater table. The following liner configuration were evaluated:

- Double-composite (See Figure 4)
- Single-composite (See Figure 5)
- Double liner (See Figure 6)

These configurations were selected based on the design and performance requirements in NJAC 7:26.2A(5), discussions with NJDEP staff, evaluation of site conditions, and consideration of possible remedial measures. The double liner system was selected for the following reasons:

- The design is consistent with the spirit of the regulations. The liner system will consist of a primary clay/geomembrane composite liner and a secondary geomembrane liner. A leak detection/collection drainage layer will be constructed between the primary and secondary liner systems. Given the nature of the ground water, the proposed ground improvements and assumed remedial actions, the proposed liner design will exceed the minimum performance requirements specified in NJAC 7:26-2A.6(e)(3), which


(a) Northern Setback

(b) Southern Setback

(c) Eastern Setback

(d) Western Setback

85'
30'
25'
20'
10'
EL = 12
GWT
Clay
75'
200'
225'
3
1
Key
① Hackensack River
② Sheet Pile (Optional)
③ Flood Control Dike
④ Access Road
⑤ Ditch
⑥ Landfill
⑦ Slurry Wall - by Koppers
⑧ Dock Area
⑨ RR Embankment
⑩ Clear Zone

FIGURE 3. VARIABLE SETBACK DISTANCE, ALTERNATIVE D

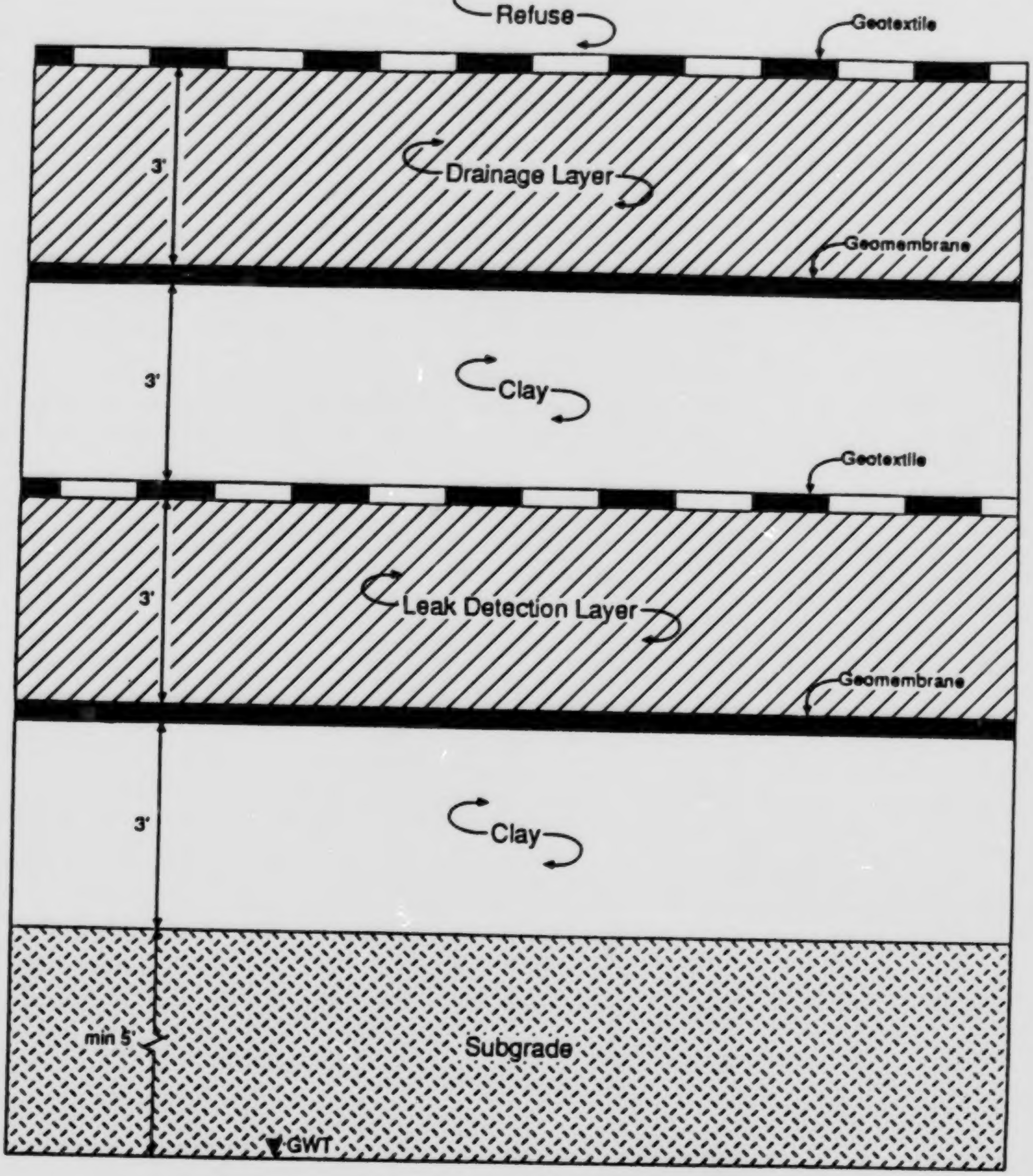

Refuse
Geotextile
3'
Drainage Layer
Geomembrane
3'
Clay
Geotextile
3'
Leak Detection Layer
Geomembrane
3'
Clay
min 5'
Subgrade
GWT

FIGURE 4. DOUBLE-COMPOSITE LINER SYSTEM

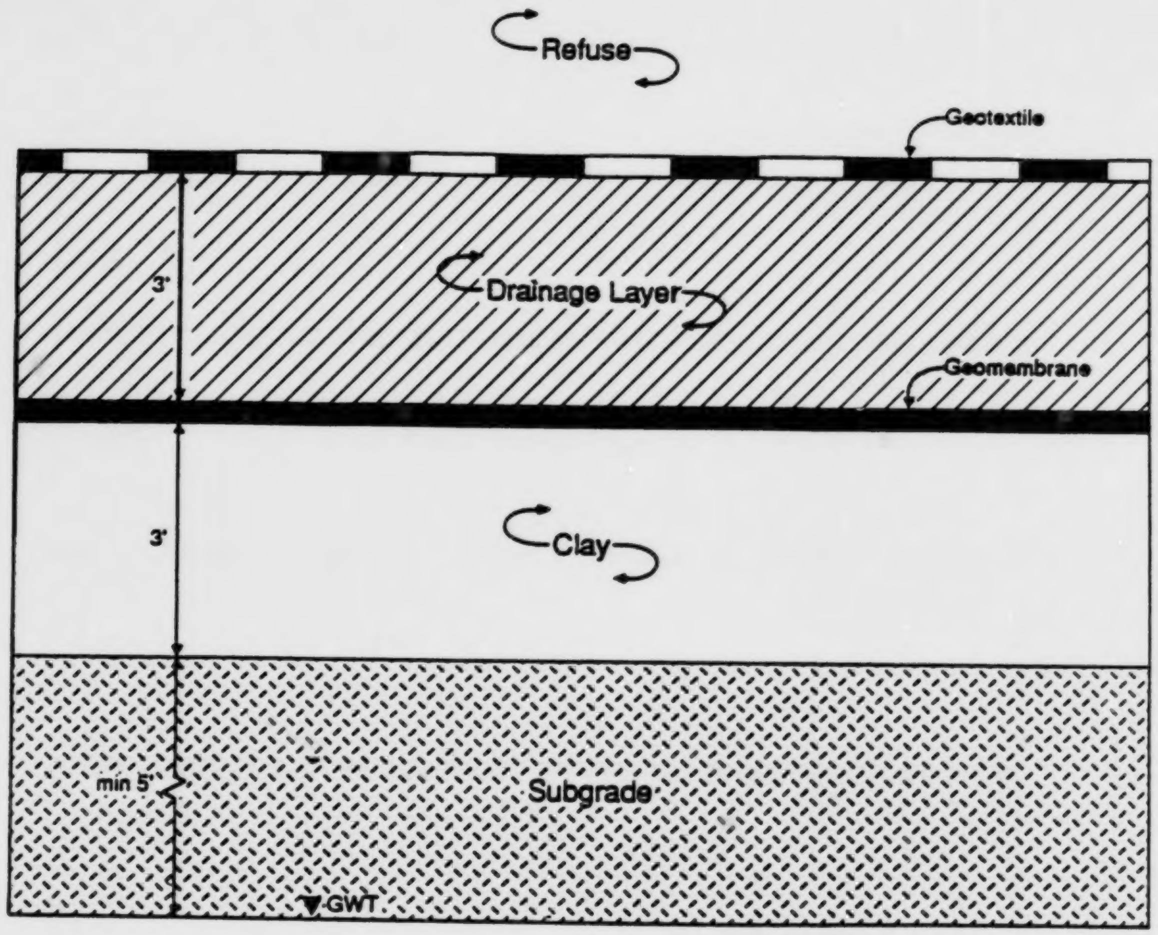

Refuse
Geotextile
3'
Drainage Layer
Geomembrane
3'
Clay
min 5'
Subgrade
GWT

FIGURE 5. SINGLE-COMPOSITE LINER SYSTEM

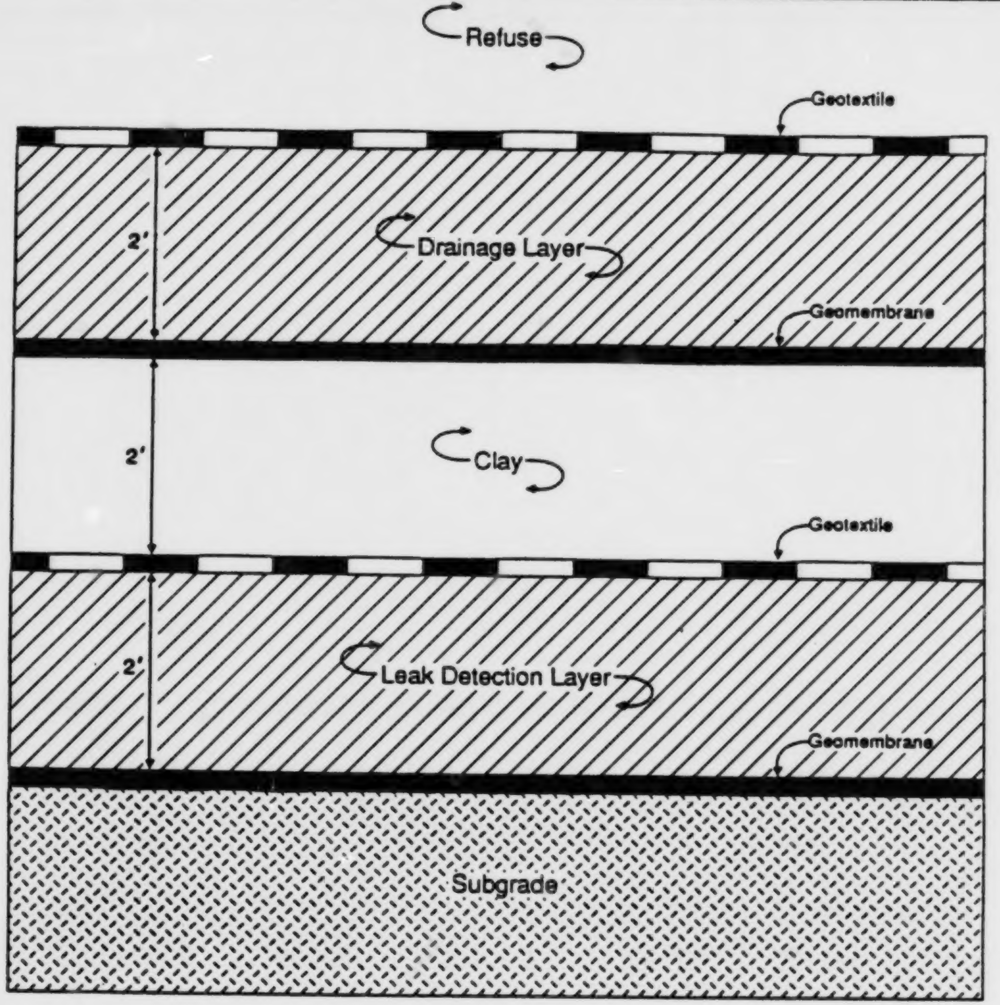

Refuse
Geotextile
2'
Drainage Layer
Geomembrane
2'
Clay
Geotextile
2'
Leak Detection Layer
Geomembrane
Subgrade

FIGURE 6. DOUBLE-LINER SYSTEM

would otherwise require, as a minimum, a double geomembrane liner system.

- Maximizes the available fill volume and meets the landfill performance standards. The area available at the site for landfill is limited. One foot of liner is equivalent to approximately 1/2-year of landfill life.
- The remedial measures by Koppers will hydraulically isolate the more permeable soils directly beneath the landfill, and discharge from the site will be substantially reduced. This in effect will provide tertiary containment. The 2-foot clay liner thickness versus the standard 0.9-meter thickness was chosen for the same reason.

Table 5 presents a summary of the sizing alternatives considered, estimated site development costs (not including foundation improvements), and estimated life of each.

Geotechnical Investigations

The geotechnical investigation of the landfill site focused on evaluation of the subsurface conditions that would impact the development of the landfill. The stability analyses for the landfill indicated that without improvements, the subgrade is unstable at fill heights of 6 m to 12 m in certain areas of the landfill, and settlements of up to 3 m could occur under the maximum fill height of 27 m in the center of the site. Constructing the landfill to a fill height of 12 m would not provide sufficient disposal capacity, and the settlement associated with greater fill heights could compromise the liner and leachate collection systems.

The following technologies were considered to improve the existing subgrade[9]:

- Settlement control:
  - Preloading the site with sand surcharge
  - Preloading the site with a sand surcharge and wick drains to accelerate consolidation
  - Structural piles or stone columns
- Stability control:
  - Preloading the site with a sand surcharge (with and without wick drains) to increase the shear resistance of the cohesive soils.
  - Structural piles or stone columns
  - Piles and load distribution mat

Multiple fill heights were evaluated for each alternative. Construction cost estimates were prepared for each alternative. The difficulties of construction and scheduling were identified. Environmental and health risk were assessed. The conclusion of the analysis are summarized below:

- Construction difficulties and scheduling: All the alternatives considered for improving the foundation soils would be difficult to construct. However, the preload and wick drain alternative would require substantial, long-term earthwork operations and geotechnical monitoring. In addition, maximum long-term settlements of up to 1.4 m in the center of the site could be managed by superelevating the liner. This magnitude of settlement is not desirable. Both the structural pile and stone column alternatives would be difficult to install due to subsurface

TABLE 5

COMPARISON OF ALTERNATIVE CONCEPTUAL LANDFILL DESIGN CONFIGURATIONS

Alternative		Liner Type	Slope Angle (H:V)*	Setback (ft)	Available Volume (1000 cy)	Disposal Rate (cy/day)	Estimated Life (years)	Site Development Cost# ($ million)	Cost ($/cy)
1A	(3-3)	SC	3:1	300	292	330	7.4	15.2	17.0
1B	(3-3)	SC	3:1	150	2,003	330	16.6	19.4	9.7
1C	(3-3)	SC	3:1	110+	2,299	330	19.1	23.6	10.3
1D	(3-3)	SC	3:1	80++	2,463	330	20.4	24.6	10.0
1D	(3-2)	SC	3:1	80++	2,525	330	21.0	22.8	9.0
2A	(3-3-3)	DC	3:1	300	689	330	5.7	24.4	35.4
2B	(3-3-3)	DC	3:1	150	1,654	330	13.7	33.1	20.0
2C	(3-3-3)	DC	3:1	110+	1,951	330	16.2	39.6	20.3
2D	(3-3-3)	DC	3:1	80++	2,095	330	17.4	41.5	19.8
3A	(3-3-3)	D	3:1	300	790	330	6.6	20.7	26.2
3B	(3-3-3)	D	3:1	150	1,828	330	15.2	26.6	14.6
3C	(3-3-3)	D	3:1	110+	2,125	330	17.6	32.4	15.2
3D	(3-3-3)	D	3:1	80++	2,279	330	18.9	33.9	14.9
3D	(2-3-2)	D	3:1	80++	2,341	330	19.4	30.2	12.9
3D	(2-2-2)	D	3:1	80++	2,403	330	20.0	27.7	11.5
4		D	4:1	110	1,592	330	13.2	32.4	20.4

SC = Single composite liner, 40 mil HDPE and 3 feet of clay

DC = Double composite liner, 2 single composite liners with a 3-foot leak detection layer

D = Double liner, primary liner = single composite, seconedary liner = 40 mil HDPE, leak detection system in-between

3-2 - Refers to clay-drainage layer thicknesses, in feet, respectively

3-3-3 - Refers to leak detection-clay-leachate collection layer thicknesses, in feet, respectively

' - See Table 1 for assumed waste disposal rates at the landfill

+ - Alternative with access road between flood control dike and the landfill, See Figure 2.7

++ - Alternative with access road on-top of dike, see Figure 2.8

* - H = Horizontal; V = Vertical

# - Estimates to not include subgrade improvement costs.

(NOTE: This evaluation is based on conceptual design configurations. The values presented are valid for comparison.)

PURPOSES: The landfill life estimates in Section 2.6.3, which differ from these, are based on the final design.

obstructions. However, the structural pile alternative is the more conventional, well understood technology, and could be implemented within the required time frame.

- Environmental risks: Both the preload/wick drain and stone column alternatives could result in downward migration of contaminants from the upper fill aquifer to the glacial till. The stone columns and wickdrain, which are relatively porous media, could act as a conduit for transporting contaminants downward. As such, these alternatives were removed from further consideration.

Although not the least costly of the alternatives, the structural pile alternative was selected for the following reasons:

- Pile performance is well understood and documented
- Minimizes environmental and health risks
- The foundation construction can be accomplished within the project schedule.

Selected Landfill Design

The final landfill design configuration presented to the NJDEP in February 1988 consists of the following major components:

- Liner system: Double liner consisting of a primary composite liner and a secondary geomembrane liner (See Figure 6). The liner design should meet or exceed the minimum liner design standards being considered by the modifications to RCRA Subtitle D or legislation currently being considered by the U.S. Congress.
- Leachate collection: The bottom liner configuration is such that the landfill is divided into a series of 46 meter wide drainage cells. 15-centimeter diameter perforated pipes are placed in the center of the drainage cells and discharge to a main header pipe at the perimeter of the site. A typical cross section of the landfill is shown in Figure 7.
- Leachate storage/treatment: When the site is fully developed, approximately 5,300,000 liters of onsite storage will be available for emergency and contingency purposes. The HCIA has submitted permit applications to discharge the leachate to the Passaic Valley Sewerage Commission's (PVSC) sewer lines. A pump station is being designed onsite for this purpose. Leachate quantities were estimated using the HELP model. Table 6 presents the estimated leachate quantities for each phase of the landfill.
- Foundation: The design concept selected for the foundation includes the use of structural piles and a load distribution mat consisting of either reinforced concrete, compacted crushed stone, or geotextile reinforced compacted crushed stone. Additional field and laboratory investigations and design analyses are being conducted to select and design the most cost-effective foundation.
- Operation: The landfill will be constructed and operated in four phases. The first phase will consist of approximately 6 acres and will have an estimated life of 2.8 years. Ash and bypass wastes will be disposed in separate working faces to the maximum extent practical.
- Design life: The landfill is designed for a 16-year site life.

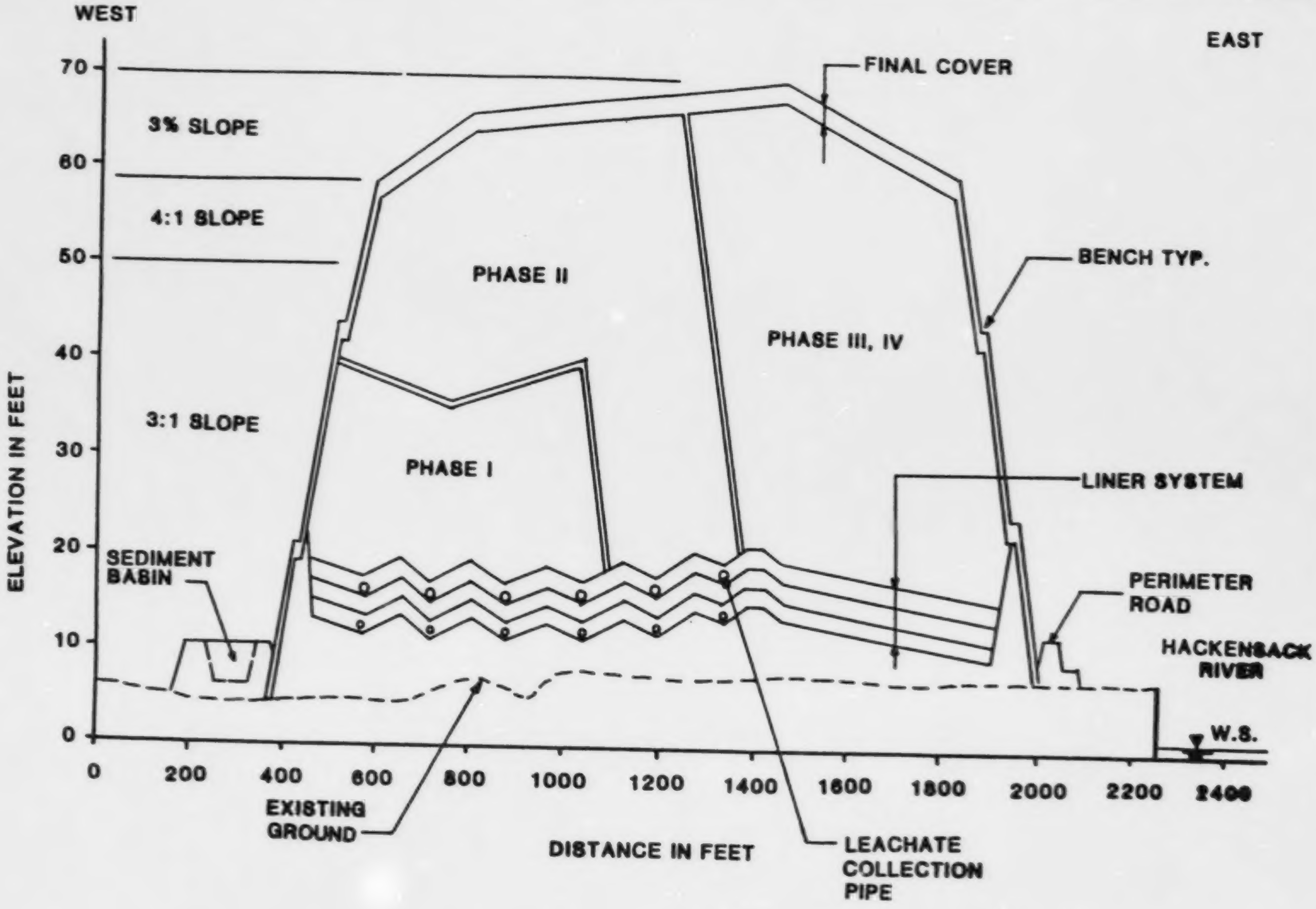

WEST
EAST
ELEVATION IN FEET
70
60
50
40
30
20
10
0
3% SLOPE
4:1 SLOPE
3:1 SLOPE
FINAL COVER
BENCH TYP.
PHASE II
PHASE III, IV
PHASE I
LINER SYSTEM
SEDIMENT BASIN
PERIMETER ROAD
HACKENSACK RIVER
W.S.
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
EXISTING GROUND
DISTANCE IN FEET
LEACHATE COLLECTION PIPE

FIGURE 7. TYPICAL LANDFILL CROSS-SECTION

TABLE 6

ESTIMATED LEACHATE GENERATION

Phase of Ashfill Development	Estimated Completion Date *	Area Covered by Liner (acres)	Average Thickness of Waste Layer (feet)	Leachate Production (gpd)	
				Average Annual	Peak Daily
I	February 1994	14	34	26,700	145,600
II	May 1999	19	37	36,100	191,100
III	April 2004	28	40	52,000	268,200
IV	April 2007	37	43	68,800	344,400

* Assumes filling commences in April 1991.

The landfill development cost, excluding the foundation improvements, is estimated at $33 million (1987 U.S. dollars). The foundation improvements costs are estimated to range between $122 and $140 million. The total cost for the landfill is substantial; however, an analyses of the long-term costs of out-of-county hauling indicated that proceeding with the landfill construction, even at this premium cost, is the less costly alternative, and the County has control over its own destiny.

CONCLUSION

The HCIA submitted the permit application and environmental health and impact statement for the landfill in February 1988. The NJDEP currently is reviewing the permit application and supporting documents. The HCIA hopes to begin construction of the facility in late 1990 or in early 1991. The facility needs to be operational by early 1992, which is when the MSWI is scheduled to be on-line.

Final designs and construction plans are being prepared for the landfill and the foundation improvements. The first phase construction will include the first phase of the liner/leachate collection system, an administrative and maintenance building, leachate storage facilities, a pump station, access roads, a monitoring network, and other utilities.

The HCIA has selected a solid waste management plan which includes recycling, resource recovery, and state-of-the-art land disposal technology to handle its solid waste needs. The cost of the plan is substantial, but the alternatives are more costly in the long-term. With the selected plan, the County is able to manage its own solid waste disposal instead of relying on out-of-county hauling and disposal, for which they have limited control.

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10-5-88

HOW ENVIRONMENTAL RISK FROM LEACHING OF HEAVY METALS IN ASH RESIDUES FROM COMBUSTION OF MUNICIPAL SOLID WASTE CAN BE MINIMIZED BY CONTROL OF COMBUSTION, EMISSIONS AND ASH RESIDUES MANAGEMENT

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ABSTRACT

Designers and operators of municipal waste combustors can achieve minimum environmental risk due to discharges of gaseous emissions to the atmosphere by applying effective combustion controls and emission controls, and minimum leaching of heavy metals from ash residues and recovered ash products to the environment if they know what factors have an effect on the mobility (solubility) of heavy metals which need to be controlled, how to influence or manage these factors, and what monitors and measurements are needed to maintain control.

Environmental risk can be lowered by reducing metals content in the waste to be burned; by controlling combustion air so as to avoid excessive flame temperatures and minimizing lifting of particulate rising from the bed; by using alkaline reagents to absorb acids which may solubilize metals; by minimizing scrubbing temperatures to reduce excess lime in the flyash; by removing soluble metals from the ash by washing or other treatments; by encapsulating metals to prevent their leaching, and by isolating residues from the environment by applying suitable landfill management. Dependence on landfills can be minimized by making constructive use of bottom ash and flyash.

INTRODUCTION

It is well known that municipal solid waste (MSW) contains significant amounts of heavy metals such as lead and cadmium which potentially can become soluble (mobilized) and consequently represent a risk to health and environment. However, it is not generally recognized that the major portion of these metals is not available for dissolving in water. This paper cites evidence that only low concentrations of lead and cadmium are actually found in leachates from landfills devoted to municipal solid waste (MSW) and ash residues from MSW or their mixtures. In fact, actual leachates are found to contain these metals at concentrations close to or lower than the drinking water standard. Other test data shows that when ash residues are used to make concrete block, the metals are also not found to be subject to leaching.

In spite of these findings the Extraction Procedure (EP) and Toxic Characteristic Leaching Procedure (TCLP) laboratory tests, which are specified in order to identify wastes having potentially hazardous characteristics do show that these metals can be leached at high concentrations due to the addition of acid in these procedures. Data from such tests have been found to be extremely variable, and ash samples occasionally fail these acid-forced tests. In addition, some ash residues from plants with acid gas controls, have failed due to excessive alkalinity of the ash.

Even though these laboratory leaching tests have not been found to simulate leaching conditions in real landfills not those resulting from constructive use of ash residues, many jurisdictions now require regular and frequent testing of ash residues. Failure to pass tests which apply acids to force leaching has become a basis for stating that these residues exhibit the characteristic of a hazardous waste. This has led to spending over $300,000 per year for testing, and the requirement that ash residues be sent to hazardous waste landfills at costs exceeding $100 per ton of ash residue.

This situation has threatened or even led to closing of Waste-to-Energy plants, and forced a concerted effort of research and experimentation. The ASME Research Committee on Industrial and Municipal Waste, for instance, has held a Workshop on Ash Residue Management, and is devoting strong efforts toward solution of this problem, especially emphasizing the utilization of ash residues rather than landfilling them. Similar efforts are in progress throughout the world.

This paper outlines major factors which influence the characteristics of MSW ash residues, while pointing out how they might be influenced so as to minimize the risk of adverse environmental effects from the management and use of ash residues.

COMPOSITION OF THE WASTE

The metals content of the components of the waste determines the total quantity of metals in the ash residues. However, the heavy metals which are the major concern, lead, cadmium and mercury, are distributed through the waste, including the paper and plastics, even food, are can not be eliminated even if car and small batteries are recycled, or if source reductions are made.

More important than the total metals content is the actual solubility of the potentially toxic metals at the time and location where the ash residues are exposed to leaching or body intake. Only a very small fraction of the total metals is actually in a chemical form which is available (soluble) under most conditions.

COMBUSTION OF ORGANICS

Combustion efficiently destroys the organic components of MSW, producing a compact, inorganic ash residue. With modern technology essentially all organics are destroyed, most of the acid gases and almost all of the pollutants are removed from the combustion products before they leave the stack, and concentrated in the collected particulate.[Hasselriis, 1988]

Organic materials containing sulfur, nitrogen and chlorine are converted to carbon dioxide, water, acid gases, and trace organics. It has been demonstrated that with good combustion, toxic organics in stack emissions, collected flyash, and bottom ash can be reduced to extremely low levels. Vendors of MSW combustion systems have developed sophisticated equipment to accomplish these objectives. However, there is a continuing need to define the conditions required to achieve this.

The public is concerned about stack emissions from Waste-to-Energy (WTE) facilities, about why wide variations exist, and about whether or not, after the facility completes its compliance test, the emissions would continue to be acceptable on a hour-by-hour and day-by-day basis. This concern has led to the requirement for continuous monitoring of opacity, oxygen, carbon monoxide (CO), and acid gases in the stack gases, as well as furnace temperatures, and testing of the ash residues.

Extensive research on these emissions and discharges has been undertaken to determine how they can be reduced and maintained at environmentally acceptable levels, and, most important, to find which operating parameters could be measured and controlled in order to maintain these low discharges to the environment.

Environmentally safe incineration of MSW requires control of the combustion process, control of air emissions, and proper management of the flyash and bottom ash residues. In order for designers and operators to be able to accomplish this objective, they must have information on how to do it, and instruments capable of providing necessary measurements and control.

Combustion Tests at Pittsfield

Furnace temperatures (after fully mixing secondary air) between 840 and 940°C, were found to be optimum at Pittsfield. Prior to adding secondary air the primary furnace temperatures were 70 to 100°C higher than the secondary furnace temperature, indicating that the best flame temperature range may be 910 to 1040°C. The increase in emissions at higher temperatures is probably the result of the reduction in the excess oxygen which is required to achieve higher temperatures.[Hasselriis]

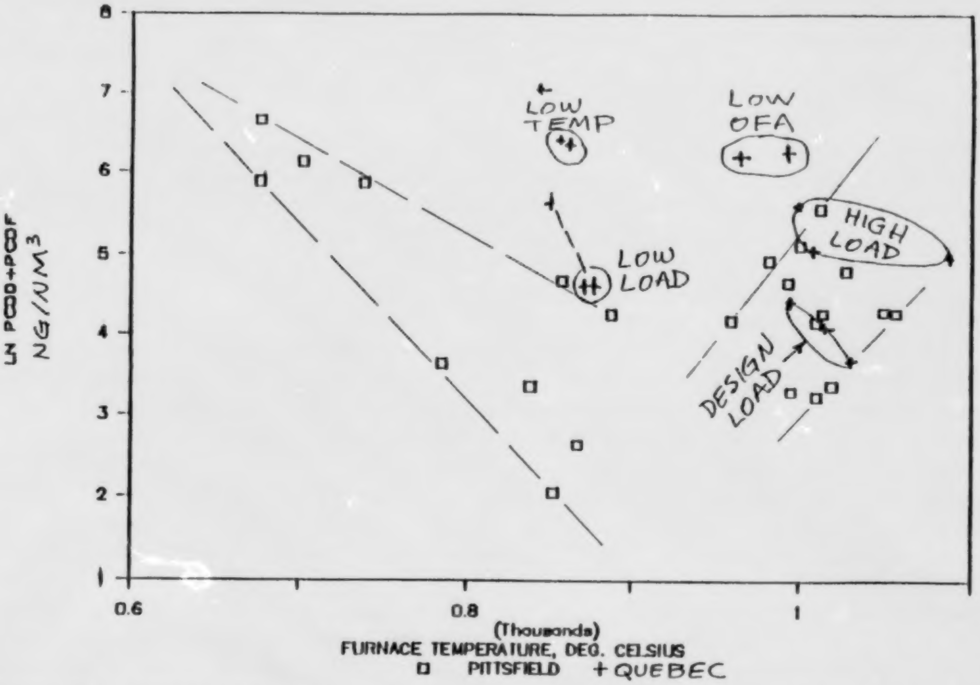

Figure 1 Pittsfield data and Quebec City data: logarithm of total dioxins (PCDD) plus furans (PCDF) versus temperature measured at exit of secondary furnace. The Quebec City data falls within the bands found from Pittsfield tests, indicating a range of temperatures resulting in minimum PCDD+PCDF emissions.

When oxygen levels are too high, the associated excess air reduces the flame temperatures; when oxygen is too low, it becomes more difficult to mix the reactants, and uniformity of destruction of organics suffers. It was noted at Pittsfield that at oxygen levels substantially above or below about 8% (dry basis) total dioxins plus furans increased.

New Data from Quebec Tests

The test data recently reported by NITEP from tests of the Quebec incinerator has generally supported the Pittsfield data. Data from these tests is shown in Figure 1 for comparison with the Pittsfield data. These tests have provided important additional information:

- The distribution of combustion air under the grate and over the fire affects the particulate emissions as well as heavy metals carried by the combustion gases out of the furnace and through the boiler;
- Measurements of carbon monoxide are useful indicators of the efficiency of combustion which results from optimum control and placement of underfire air and overfire air and effective mixing of reactants;
- Optimum conditions were found which resulted in much lower emissions than had been reported prior to this retrofit. Excessive overfire air, poor distribution of air under the grates and low furnace temperatures were found to result in much higher emissions of organics such as dioxins and furans as well as inorganics.

THE EFFECT OF COMBUSTION ON METALS

The process of combustion affects the metals in various ways. The major portion of mercury and cadmium, and some lead and chromium, follows the combustion gases due to volatilization, ultimately becoming part of collected flyash, the remainder ending up in bottom ash residues. The lead and cadmium in paper and plastics is mostly vaporized, whereas the fate of these metals in batteries and other solid forms is uncertain.

The management of combustion air, hence flame temperatures, determines to a significant extent how much of these metals are vaporized, as found from the tests of the Prince Edward Island starved-air incinerator. The same is true for furnace systems using flue gas recirculation to reduce flame temperatures in the combustion zone, such as the technology tested in Pittsfield.[MRI]

The recently published results of testing of the retrofitted Quebec City incinerator show that particulate emissions were greatly reduced under optimum combustion air settings, due to reduced lifting of particulate from the bed, lowering the height of the flame, and reducing flame penetration into the boiler.[NITEP, 1988]

As the combustion gases cool, the metals condense on particulate matter. The presence of chlorine and sulfur in the MSW causes varying amounts of mercury, lead and cadmium to form chlorides and sulfates, a process which is inhibited by the presence of alkaline materials present in the particulate. Lime injection can substantially influence these reactions.

The particulate matter carried by the combustion gases, as well as the deposits which form on furnace and tube surfaces in boilers, are sites where chemical reactions take place, affecting the chemical form of the heavy metals.

Flame temperatures and the relative amounts of excess oxygen affect these reactions strongly; both oxidation and reduction may take place, perhaps cyclically. As a consequence, the form of metals in flyash from combustion is highly variable both as to quantity and chemical composition.

ASH RESIDUES

The ash residues from combustion of MSW include bottom ash, flyash and boiler hopper ash, flyash collected by the emission controls, and flyash mixed with acid gas scrubber reaction products and excess lime. These residues are collected in two or more places, and must be disposed of either separately or mixed together. In the past, facilities without acid gas controls have generally mixed the flyash with bottom ash before disposal, although in Europe where bottom ash was used for roads flyash was sometimes not mixed with the bottom ash to minimize metals contamination.

Bottom ash residues consist mostly of metals, granular aggregate, which can be recovered and used beneficially, and fine ash similar to flyash although generally coarser. These residues have generally been mixed with flyash for disposal, since they are compatible when mixed in a wet or damp condition.

Ash Residue Management

The methods of handling the flyash, scrubber residues and bottom ash are major factors in determining the solubility or leachability of heavy metals in these residues. If the residues are well mixed, the leachability approaches that of the bottom ash, since there is much less flyash. If they are not well-mixed, however, pockets of flyash can be collected during sample collection, causing severely unrepresentative test data. This is especially important when the flyash contains higher levels of soluble metals. To avoid such pockets, flyash and bottom ash must be mixed well, avoiding surges due to rapping an ESP or cleaning a fabric filter, or surges and gaps in bottom ash flow.[Hasselriis]

The degree to which flyash, scrubber residues and bottom ash are wetted by the process can have a major effect on the chemical forms, hence the solubility of the heavy metals. When ash is discharged into a quench tank, the water will absorb soluble salts and metal compounds. When dry flyash added to damp bottom ash and tested for metals solubility, it was found that different metals solubilities were found than when the flyash was wet before mixing.[Hjelmar] These tests revealed the importance of water reactions as well as the amount of time allowed for reactions to take place. Many reactions of moisture and ash residues take hours or days to take place.[Hjelmar]

Ash residues from plants without lime scrubbers is porous like sand, assuring rapid leaching as water passes through. Extensive tests of Westchester ash residues showed that the leachate had a pH which was neutral to alkaline, and that the leachates collected from laboratory leaching with simulated acid rain contained concentrations of lead and cadmium which were close to or less than the drinking water standard.[Cundari] The Saugus RESCO ash pile was washed clean by rainwater to a depth of about 16 feet in about three years, as indicated by samples passing the EP leaching test.[Feder] After 12 years the entire 45 foot pile feet was clean, and heavy metals were not found in the leachate at the detection level at the base of the pile.[Wehran]

Beneficial Use of Bottom Ash

Ash residues, either mixed with flyash or bottom ash only, have been used for road construction and other applications for many years all over the world. Recent concern about the heavy metals has interrupted many arrangements to use these materials. In the face of these concerns, the Danish government has established regulations for the use of bottom ash residues for roadbase and other uses, which restricts the quantities which can be used without applying for a permit, and the distances at which specific uses can be located from wells used as drinking water sources. These regulations are based on data which simulate the rate of leaching and the concentrations of metals which would be found in ground water after rain passed through these residues.

There are many uses for ash residues other than roadbases, including asphalt pavements (essentially encapsulating the ash). Concrete blocks made from mixed flyash and bottom ash residues have washed with rain and the leachate found not to have dissolved heavy metals at the detection level. Blocks tested in marine reefs were also found not to have lost heavy metals by leaching in sea water, and marine life thrived on both normal concrete blocks and those made with ash residues.[Roethel]

Ash Residues with Acid Gas Controls

When acid gas controls are used to absorb sulfur dioxide and hydrogen chloride, further and highly significant chemical reactions take place which affect the solubility of heavy metals in the flyash and scrubber residues. Instead of highly soluble chlorides, insoluble hydroxides and carbonates may form, while lime becomes highly soluble calcium hydroxide.

Test data which is available today indicates that the solubility of heavy metals in scrubber/flyash residues may be low, and that these materials may pass the acid leaching tests.[Borio] However, it is also apparent that the scrubbing of acids has greatly increased the amount of soluble salts in the flyash. These cause leachates from scrubber/flyash residues to have high total solids and soluble salt contents, which must be dealt with in the disposal of leachate.

Management of Residues in Ashfills

Recent studies of leachate from sanitary MSW landfills, ash/MSW landfills, ashfills, and ash quench tanks revealed the striking similarity of leachates from these various sources. The pH, organics, salts and metals were similar except that organics were substantially less in the case of ashfills. Perhaps this is not surprising since they all came from MSW, and organics are destroyed by combustion.[Roffman]

When ash residues are washed by water, the heavy metals leach out at rates determined substantially by the pH of the leaching water and the concentration (strength) of acid or alkalinity. If acid water is applied, the natural alkalinity of the ash residues reacts with and consumes (buffers) the acids. Calculations of how long it would take for acid rain to deplete this buffering ability range indicate several hundred to several thousand years would be needed. Long before this time the metals would have been leached out.

The speed at which ash can be washed free of metals depends on the amount of water passing and the pH which results from interaction of the water with the residues. If the pH is such that solubility is low, the leachate will have low concentrations of heavy metals. Leachate from actual MSW landfills and ash fills shows high concentrations of soluble salts, similar to sea water, which constitute the problem of disposal or treatment of the leachate, and a rapid reduction in concentrations in the first few washes, indicating depletion of these salts and, ultimately, the soluble metals.[Hjelmar]

How rapidly the salts and metals are depleted from an ashfill depends upon much rain falls on the fill, and how readily the rain can penetrate the top surface. The permeability of the ashfill containing scrubber residues is generally low, depending on how it is managed, hence will restrict leaching.

When acid gas controls are used, the ash residues have radically different physical as well as chemical properties from those of plants without scrubbers, which make them especially secure from leaching when placed in landfills. With better understanding of these materials it may also be possible to use them beneficially as construction materials, thus minimizing landfill.

When lime scrubbing is used, pozzalonic reactions can take place, depending on the moisture present, the quantity of excess lime, how well mixed the residue is, and the degree of compaction. These reactions tend to encapsulate the heavy metals in insoluble coatings so that they will not leach out under any natural circumstances. Portland cement and lime have been widely used to further encapsulation and immobilization of metals, especially the flyash residues. The excess lime used in scrubbing may have to be augmented for optimum results.

Scrubbing Temperature: a Major Factor

In the range of temperatures where condensation of organic and inoganic vapors can take place, scrubbing temperature is a major factor in the effectiveness of emission controls. At temperatures below about 280°F sulfur dioxide, hydrogen chloride and most heavy metals, as well as dioxins, furans and heavy metals, are effectively removed, primarily by condensation on particulate. At lower temperatures mercury removal becomes effective.

Dry powder injection has been shown to be as effective in removing acid gases and metals as spray-dry scrubbers, at these temperatures. This has been confirmed by exhaustive tests of a pilot plant attached to the Quebec City incinerator. These tests, performed under the National Incinerator Testing and Evaluation Program (NITEP) show extremely low emissions of heavy metals, dioxins and furans, measured after the scrubber/fabric filter when the gas temperatures were held below 140°C (280°F). Even though the incoming PCDD and PCDF were high, in the range of 1,000 ng/m^3, indicating relatively poor combustion, the outlet was below detection limit or at most 1 ng/m^3. The removal efficiency was thus higher than 99.9% for dioxins and furans at 140°C, when using either dry lime injection or spray-dry (lime slurry) scrubbers.

TABLE I: REMOVAL EFFICIENCIES OF ACID GASES [NITEP]

POLLUTANT		INLET (ppmv)	OUTLET (PPMV)	% REMOVAL EFFICIENCY
SO_2	(140°C)	100	41	58
	(125°C)	118	10	92
HCl	(140°C)	475	29	94
	(125°C)	464	9	98

Temperature Versus Excess Lime

The NITEP tests show that while increasing the quantity of lime used in scrubbing has an effect on removal efficiencies at temperatures over 140°C, at lower temperatures, especially below 125°C, even a lime-to-acid ratio (stoiciometric ratio) as low as 0.8 was almost as effective in achieving over 90% SO_2 control as a ratio of 1.0 or 1.2. A stoichiometric ratio of 1 means the exact amount of lime to cancel the acid.

This finding is important, not only in achieving high removal efficiencies, but also in economizing in lime. Even more important may be the avoidance of excessive lime in the ash residues, since excess alkalinity can act to mobilize heavy metals.

Soluble Heavy Metals in Ash Residues

All of the heavy metals which are present in MSW are collected in flyash or bottom ash except for trace quantities which are emitted with the stack gases. While laboratory and field tests show that only a small percent of these metals actually leach out under normal conditions, the fraction of these metals which could be leached out of ash residues, especially the flyash, is a matter of concern, since if these residues were not managed properly, metals dissolved in water or leachate might find their way into the environment at unacceptably high concentrations which could contaminate ground water, possibly even drinking water.

In order to be assured that ash residues are handled so as to represent no significant threat to the environment, it is necessary to have a means of testing which corresponds with the contemplated management methods.

The Extraction Procedure Toxicity Test

The Extraction Procedure (EP) Toxicity test was developed in order to simulate a worst case method of ash disposal: in an acid-producing MSW landfill. If the ash sample failed this test, it would be considered risky to dispose of this ash in such a landfill, if the leachate from the landfill could leak into groundwater. The EPA Extraction Procedure (EP toxicity) test, and the proposed Toxic Concentration Leaching Procedure (TCLP) test developed for the Resource Conservation and Recovery Act (RCRA), use an acetic acid solution to 'force' the leaching and to maintain a pH around 5 in order to rapidly extract the metals. These tests were designed to fit the scenario that about 5% ash residue would be mixed with 95% MSW or other wastes which could generate acid conditions at a pH of 5 as they decompose, and that the landfill did not have liners to prevent escape of leachate into the ground.

The amount of heavy metal extracted during the EP and TCLP tests depends upon the buffering ability of alkaline components of the ash residues which resist the acid added during the test. The American Society for Testing Materials (ASTM) procedure, the SWP-946, and other methods use simulated acid rain or distilled water to simulate conditions where the residue is used in road construction or placed in cells separated from MSW in a landfill. Such tests would be more appropriate for measuring the potential effect on the environment of these methods of use or disposal of ash residues.

The EP toxicity test was developed based on data obtained at Oak Ridge National Laboratories. The municipal waste leachate produced at ORNL for use as a leaching agent had a pH range from 5.6 to 8.9. [Francis and White, 1987] This report presents results comparing four leaching procedures, WET (California method), EP (EPA extraction procedure), carbonic acid, and acetate buffer. When distilled water was used to leach resource recovery ashes the pH ranged from as low as 5.9 to a maximum of 11.2, according to Francis.

Table II
CONCENTRATIONS IN EXTRACTS OF RESOURCE RECOVERY ASHES
mg/l (parts per million) [Francis]

Plant:		Chicago	Sumner	Hampton	Auburn
Cadmium:					
	WET Test	1.6	0.81	1.52	0.18
	EP	0.71	0.24	0.50	0.02
	Acetate	0.19	0.52	0.33	0.03
	Carbonic Acid	0.016	0.012	0.07	0.005
	Water	<0.0005	<0.0005	<0.0005	<0.0005
Lead:					
	WET Test	29.0	35.0	46.0	29.0
	EP	5.8	6.4	10.3	3.15
	Acetate	0.5	0.28	1.62	4.2
	Carbonic Acid	0.025	0.004	0.095	0.012
	Water	<0.002	<0.002	<0.002	<0.002

Table II shows the ORNL test results comparing the WET, EP and acetate tests, using acid addition to the leaching water, with carbonic acid (simulating acid rain), and distilled water as the leaching fluid. Comparing the results for Cadmium with the EP limit of 1 ppm, it is apparent that the Chicago and Hampton samples failed the WET test, and high numbers were found for the EP and acetate tests; carbonic acid numbers were low, and water tests were below the detection limit. The lead tests show excedences of the limit of 5 ppm in all WET and EP tests, and some high numbers in the acetate tests, but carbonic acid numbers were low, and water tests showed below the detection limit. These data show how much the leaching procedure affect the concentration of metals in the leachate.

The variation in leaching of metals is the result of the sensitivity of certain metal compounds, particularly chlorides, to the acidity or alkalinity of the leaching water. It is well known, for instance, that lead and lead-containing solder can be leached from drinking water pipes at excessive rates when the pH of the water is too low. Drinking water is maintained at pH levels above 7 or so in order to prevent heavy metal leaching.

The leaching characteristics of flyash combined with lime scrubber residues are shown in Figure 2.[Donnelly] This graph actually shows the leaching characteristics of lead and cadmium. The concentration of these metals found in the leachate is shown as a function of the pH of the leachate after thorough mixing with the TCLP acid solution. Lead and cadmium are highly soluble at a pH of 5 or so, but are not found at the detection limit at pH values from about 7 to 9. The solubility of lead increases again, however, at pH values above 9, reaching the same level at about 12 as was found at pH of 5. Cadmium does not display this characteristic.

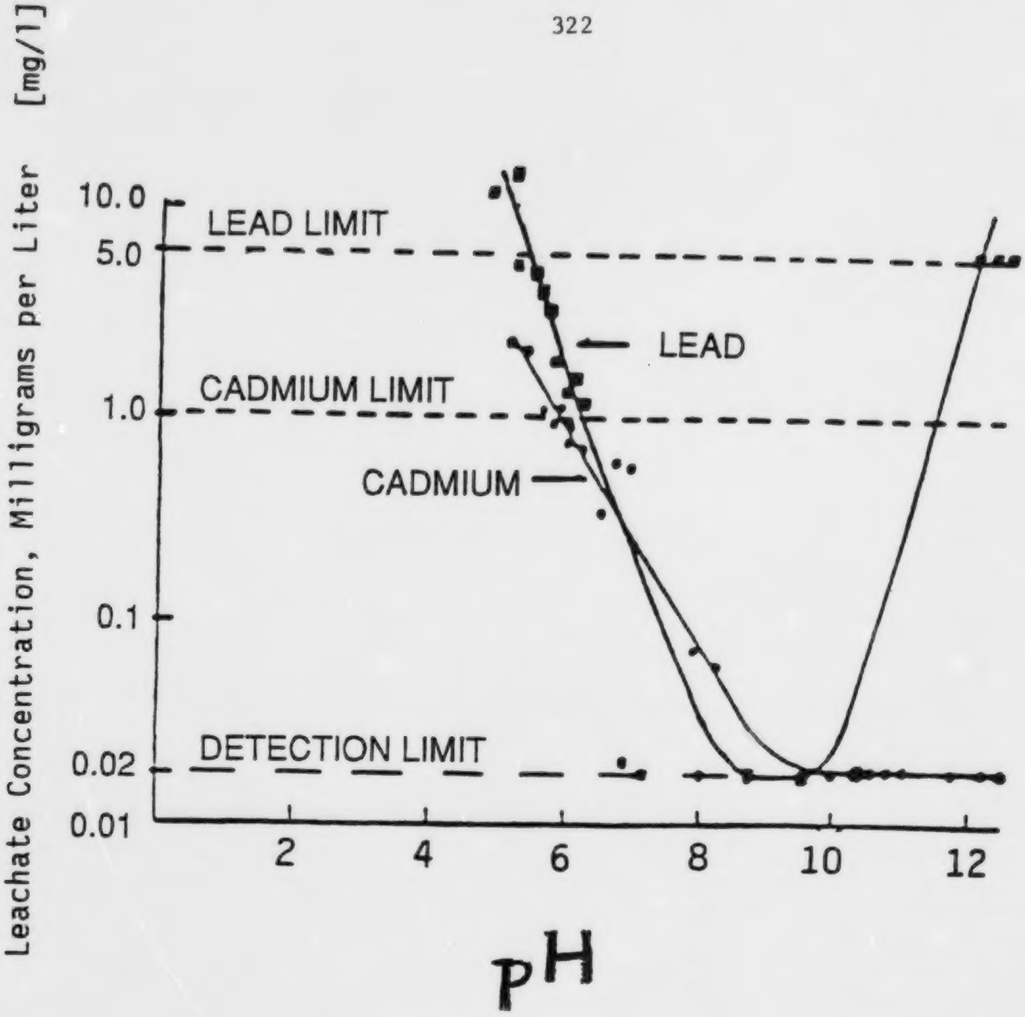

Figure 2 Solubility of lead and cadmium of acid gas scrubber plus flyash product, as a function of the pH of the leaching solution, by TCLP method. The EPA limits for lead and cadmium are noted. Note that a pH of 5 frequently causes the leachate to exceed the limits, whereas at pH between 8 and 10 solubility is below the detection limit of 0.02 mg/l. Above 10 lead solubility increases and exceeds the limit at pH = 12.[Donnelly]

Excessive alkalinity is a condition which must be avoided unless the residues can be kept under conditions where leaching will not take place, or all leachate can be collected and properly treated for disposal. The use of lime (calcium oxide) for acid gas scrubbing can result in raising the pH of the flyash-scrubber residues to levels as high as 12.4, causing release of lead even when the leaching solution was originally acidic. To avoid this problem, the lime addition may be restricted, or other chemicals or materials may be used. Alternatively, if the lime participates in pozzalonic reactions which encapsulate the metals, leaching risk may be minimized or eliminated.

TABLE III
ACTUAL LEACHATE COMPOSITION VERSUS COLUMN LEACHING DATA
Parts per Million (ppm)

	Disposal Site 1	Leaching Column Incin. A	Drinking Water Standard
pH of Leachate:	8.7 - 10.5	8.7 - 9.6	6.5 - 8.5
Total dissolved Solids	15,800 - 51,200	27,000 - 30,000	
Chlorides	3,700 - 11,400	12,400 - 15,500	
Sulfates	1,950 - 4,900	2,060 - 2,130	
Arsenic	0.006 - 0.025	< 0.002	1.000
Lead	<0.0005 - 0.019	<0.001 - 0.006	0.050
Chromium	<0.002 - 0.080	<0.002 - 0.012	
Cadmium	<0.0001 - 0.001	0.0004 - 0.0323	0.050
Mercury	<0.00005 - 0.0004	<0.0003 - 0.001	0.002

Ref: Hjelmar

Actual Leachates from Landfills and Ashfills

In an effort to determine whether laboratory leaching column tests would simulate actual leachates from landfills and ashfills, data from fifteen years of leachate analysis were compared with laboratory tests of residues from two different incinerators. Table III summarizes data from this Danish study of a landfill which contained some MSW, but mostly ash residues.[Hjelmar] It is apparent that the leachate composition from the column tests corresponds closely with the actual leachate samples taken over this lengthy period. The pH from the disposal site ranged from 8.7 to 10.5 while for the column it ranged from 8.7 to 9.6.

A recent study of the ash residues from the Marion County WTE facility which employs a spray-dry lime scrubber, concludes that the "EPtox and TCLP extractions are not a very realistic representation of the leaching processes the ash is exposed to after disposal in a monofill... A more realistic extraction procedure would be multiple extractions using real or synthetic rainwater. The use of acetic acid or acetate buffers is meaningless considering the disposal in "monofill," except that pH reduction is hastened compared to the use of rainwater as an extraction fluid."[Shinn]

Ash residues from plants with scrubbers are noted to be very dense, which can be compacted into firm road-like materials. The main problem with leachates from ash residues, especially from those from scrubbers, is that leachates contain high levels of salt, like dilute sea water. For this reason they must be managed properly, by a combination of chemical treatment and dilution, before they can be disposed of. They are often put back on the landfill, allowing the water to evaporate. When diluted, the heavy metal concentrations, already low, are reduced well below drinking water standards.

At the Shrewsbury, Massachusetts ashfill, controlling lime and water addition and compacting the ash residue results in a highly impermeable ashfill which sheds water. In this case the rainwater runoff constitutes the leachate, and salt and metals are relatively dilute compared with leachate which would have been collected after soaking through the ashfill.[Forrester]

CONCLUSIONS

- Furnace temperature is an important factor in volatizing heavy metals. Either too high or too low temperatures, which may be specific to the technology, show increases in both inorganic and organic emissions.
- Carbon monoxide readings are a good indicator of good combustion and mixing. Other limiting parameters such as excess oxygen, or mixing intensity, may define optimum operating conditions.
- Oxygen measured after the furnace is a primary control parameter, directly related to furnace temperature and fuel moisture. Stable control of combustion is important in order to prevent oscillations into conditions of poor combustion.
- Post-combustion control of acids, heavy metals and organics by reducing temperatures, scrubbing with lime and collecting particulate on a fabric filter, are effective in controlling emissions even when combustion is not ideal; however, good combustion reduces the quantity of organics which are collected on the particulate which must be disposed properly.
- Consistent control of lime addition to match acid concentrations is can avoid production of excess acidity or alkalinity in the scrubber and flyash products.
- Failure to mix flyash with bottom ash can result in a non-uniform product which may not consistently pass the Extraction Procedure (EP) toxicity test.
- The use of excess lime to achieve SO_2 control is reduced when temperatures are reduced to about 125°C (250°F).
- The natural alkalinity of the ash residues, including excess lime from acid gas control, buffers the release of lead and cadmium to leachate in and resists the weak acidity of acid rain.
- Good process control to maintain optimum conditions is necessary in order to produce a quality-controlled ash residue. Methods of process control and treatment of flyash and bottom ash are available which can be used to assure products which may be classified as non-hazardous, thus permitting their recycling and use rather than landfilling.
- Methods of management of ash residues in landfills determine the degree to which leaching of metals into the environment could possibly take place.

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CONTINUOUS RECOVERY OF HEAVY METALS FROM MSW INCINERATOR ASHES

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ABSTRACT

The leachable concentrations of heavy metals from ash residues from the incineration of municipal solid waste (MSW) often exceeds the Extraction Procedure Toxicity Test (EP Tox) limits, requiring these materials to be considered as a potential hazardous waste. High levels of leachable toxic metals such as Pb, Cd, and Cr, in the ash residues require consideration of treatment technologies prior to disposal or utilization of the ashes in other applications. Extraction studies revealed information on the leaching characteristics of the ashes and on the ability of the extraction solutions to separate these metals from the ash matrix. The kinetics of the Pb, Cd, and Cr extraction were determined through a series of batch extraction studies. The specific incinerator design and the equilibrium conditions strongly influenced the ash matrix and subsequently the extraction kinetics. Recovery of the metals from the extractant solution was accomplished utilizing electrochemical plating techniques.

INTRODUCTION

The problem of municipal solid waste (MSW) disposal must be addressed within the near future, as the demand for disposal is increasing, and available landfill space is at a minimum. One of the present solutions is the minimization of waste utilizing resource recovery facilities. The reduction in volume from the disposal of residual ashes (as compared to the disposal of the MSW) averages to be a 75% reduction [1]. Heavy metal concentrations extracted from MSW ashes, however, were found to exceed the EP Tox test limits, which is the procedure established by the United States Environmental Protection Agency (USEPA) in testing for leachable inorganic species from solid wastes [2]. The leachability of heavy metals from MSW ash residues must be considered, prior to disposal or utilization of these materials.

Extraction studies employing ash obtained from several resource recovery facilities provided insight to the leaching characteristics of the ashes and the dependency on the extract solution composition [3,4]. The purpose of the studies presented in this paper was to define the kinetics of the leaching process, and to allow the design of a continuous extraction process.

Incinerator Designs

Two incinerators were sampled for ash residues, one located in Canada and one in Massachusetts. The Canadian incinerator contains a three tiered vibrating grate primary combustion chamber and a secondary combustion chamber. Solids are fed to the combustion chamber using a hopper and have about a three hour residence period. Sixty percent of the combustion air is provided as underfire air, the remainder of the air is circulated above the burner beds. A full waterwall is provided in the incinerator. A shell and tube heat exchanger cools down the exit gases and fly ash, and separation of the gases and the fly ash occurs in an electrostatic precipitator.

The Massachusetts incinerator utilizes a baffled, three tiered combustion chamber in which the solids are periodically moved tier to tier via a hydraulic ram. The solid residue is quenched in the ash pit and then removed, while the gases and the fly ash pass through a secondary combustion chamber. The ash is separated from the combustion gases utilizing a charged gravel bed and a bag house. Detailed descriptions of both incinerators are available [4].

KINETICS STUDIES

Batch extraction studies investigated the ability of the extractant solution to separate and remove the metals from the ash matrix. Ashes investigated were obtained from two different incinerators, Massachusetts and Canada, and were either bottom ashes, fly ashes or a mixture of the two. The extract solution utilized was 1.0 N NaCl, acidified with HCl to achieve equilibrium pH of 3.0. This extract solution was found to be the most efficient in earlier experimentation [4]. The waste extractant was measured for various concentrations of extracted heavy metals (Pb, Cd, Cr), pH, and conductivity. The concentrations of the metals and the pH were determined up to a steady state time period, and their interdependence investigated.

Methods and Materials

The batch extraction studies investigated the ash/extractant conditions at eight different time periods, each carried out in triplicate. Five types of ashes were investigated: Canadian fly ash (CF3), Canadian bottom ash (CB), Massachusetts fly ash (MF), Massachusetts bottom ash (MB), and Massachusetts mixed bottom and fly ash (MM). Twenty four HDPE bottles containing 10.0 grams of ash (dry weight) and 200.0 ml of 1.0 N NaCl solution, acidified with HCl to achieve an equilibrium pH of 3.0, were placed on a rotary shaker. At the time intervals of 10, 20, 30, 45, 90, 180, 300, and 720 minutes, three bottles were removed and the solid and liquid portions immediately separated through vacuum filtration.

All liquid fractions were analyzed for pH, conductivity, Pb, Cd, and Cr. Metals concentration was determined utilizing atomic absorption spectroscopy.

Experimental Results

The change in the various measured variables with time was observed for each of the residual ashes utilized in the experiments. The pH was measured at various time intervals (Figure 1). Values all increased from the initial extractant pH to steady state equilibrium pH values of 3.0 ± 0.4. The

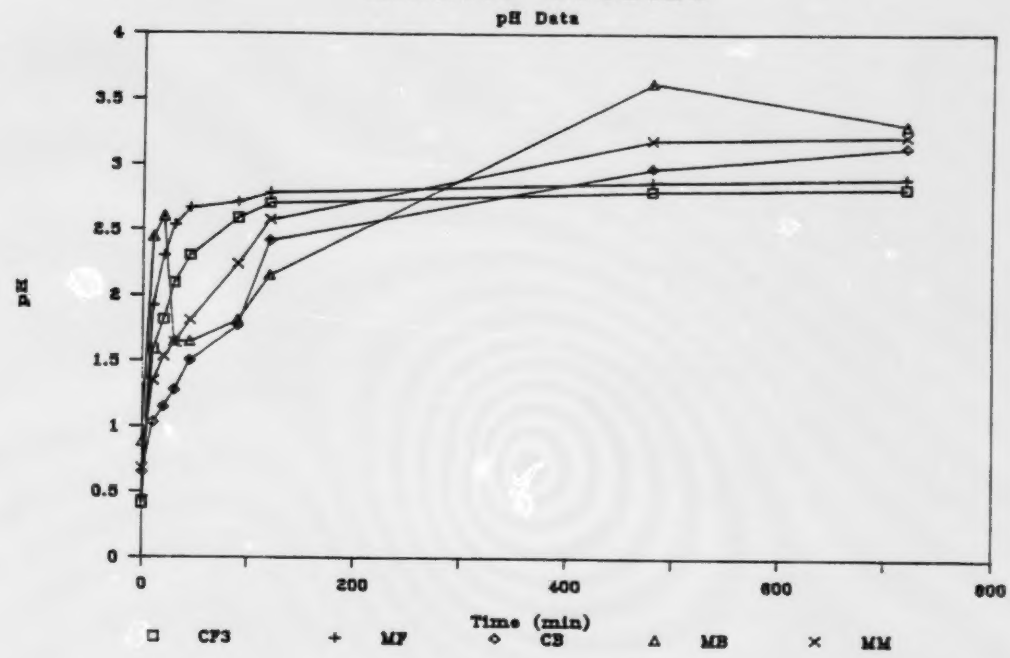


Figure 1

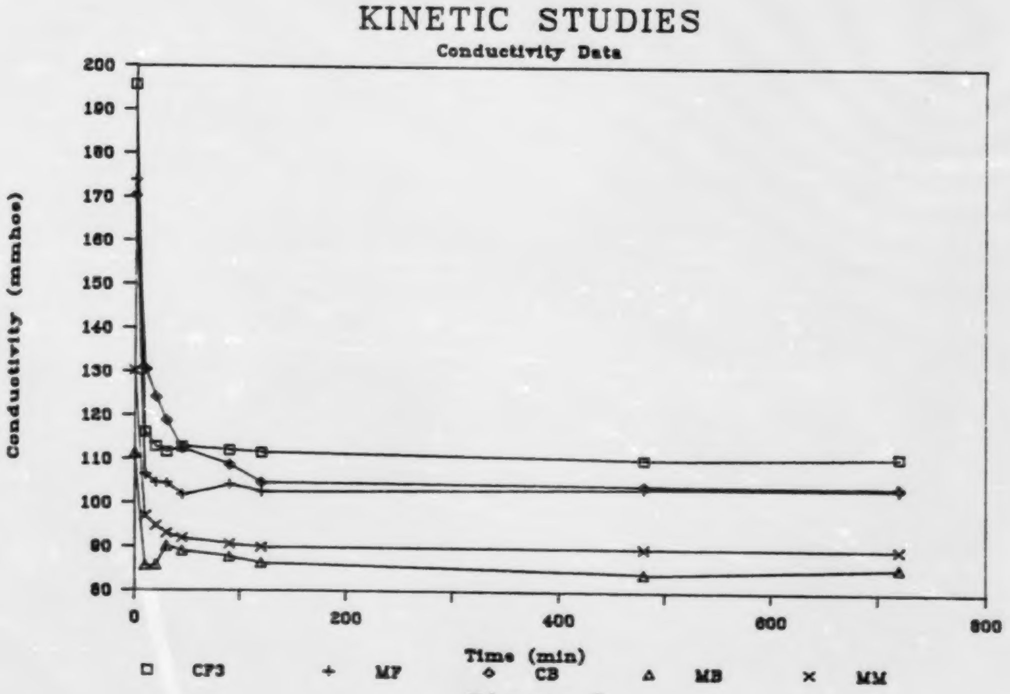


Figure 2

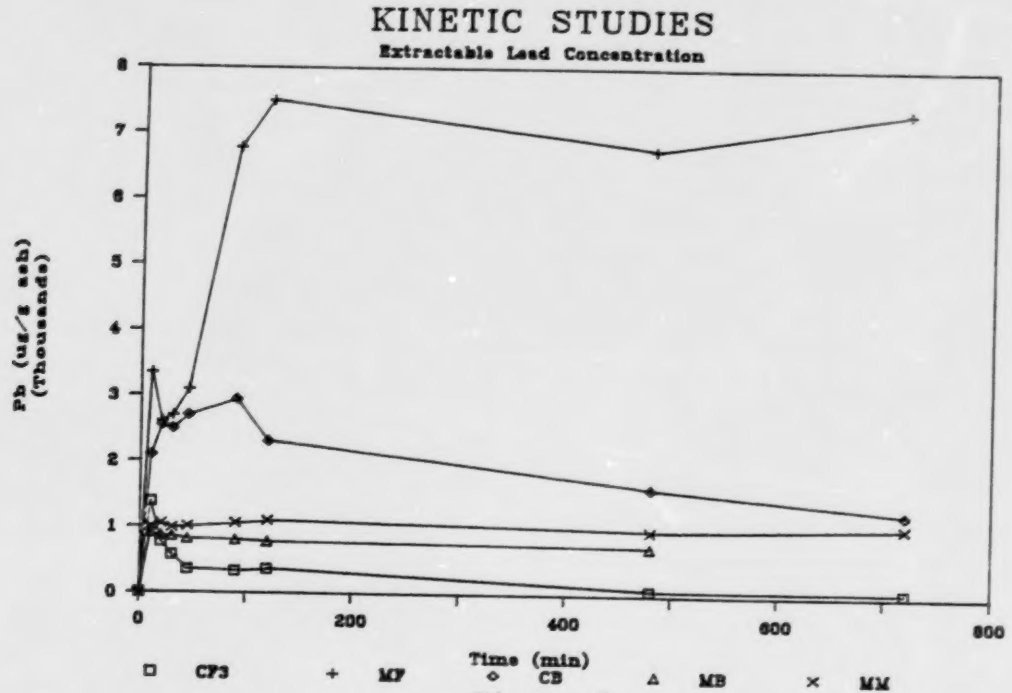

KINETIC STUDIES
Extractable Lead Concentration

Figure 3

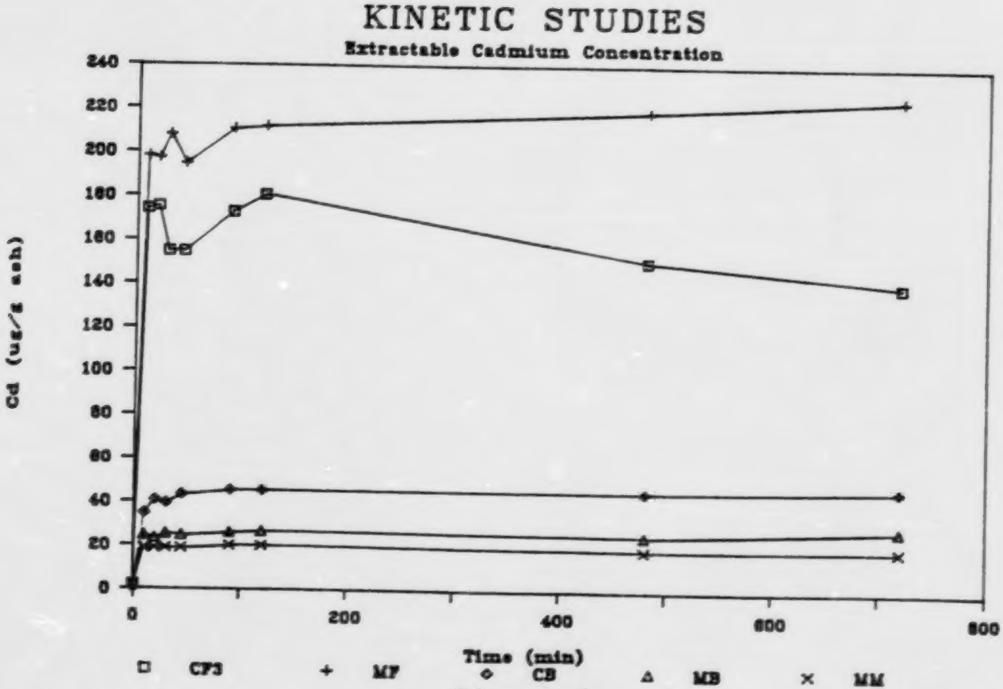

KINETIC STUDIES
Extractable Cadmium Concentration

Figure 4

differences observed in the unsteady state time period resulted from the varied structures of the ashes and their related buffering capacities. The conductance of the extracts sharply decreased from their initial values between 111.2 and 195.7 mmhos, and leveled off at steady state values between 90 to 110 mmhos (Figure 2). The trend in the change in conductance for all the ashes is that of a sharp decrease until an asymptotic value is obtained, and then the conductance is maintained through out the rest of the time period.

A definite variance is observed between the ashes for the lead concentration curves (Figure 3). The CF3 extract peaks at 10 minutes at a value of 1380 *u*g Pb/g ash, and then subsequently decreases. The CF3 lead extraction process was observed to be dependent on the pH of the system, upon comparison of the lead and pH curves for the ash. The rate of removal of lead occured at a much faster rate than the rate of the neutralization process for the ash. A similar trend was observed for the CB extract, although at a slower rate which can be attributable to the larger particle size of the bottom ash.

Extractable lead values up to 7500 *u*g Pb/g ash are achieved for the MF extract at a time period of two hours. The fly ash obtained from the Massachusetts facility exhibits a possible diffusion controls kinetics for the lead extraction procedure.

The extractable levels of cadmium for all of the residual ashes stabilized rapidly, and the removal mechanism did not exhibit a pH dependency (Figure 4). The MF extract contained the highest amount of cadmium; the concentration of cadmium in the extract increased slightly from 198.0 to 225.3 *u*g Cd/g ash. Once again, a quick stabilization was observed for the chromium concentrations for all the ashes analyzed (Figure 5).

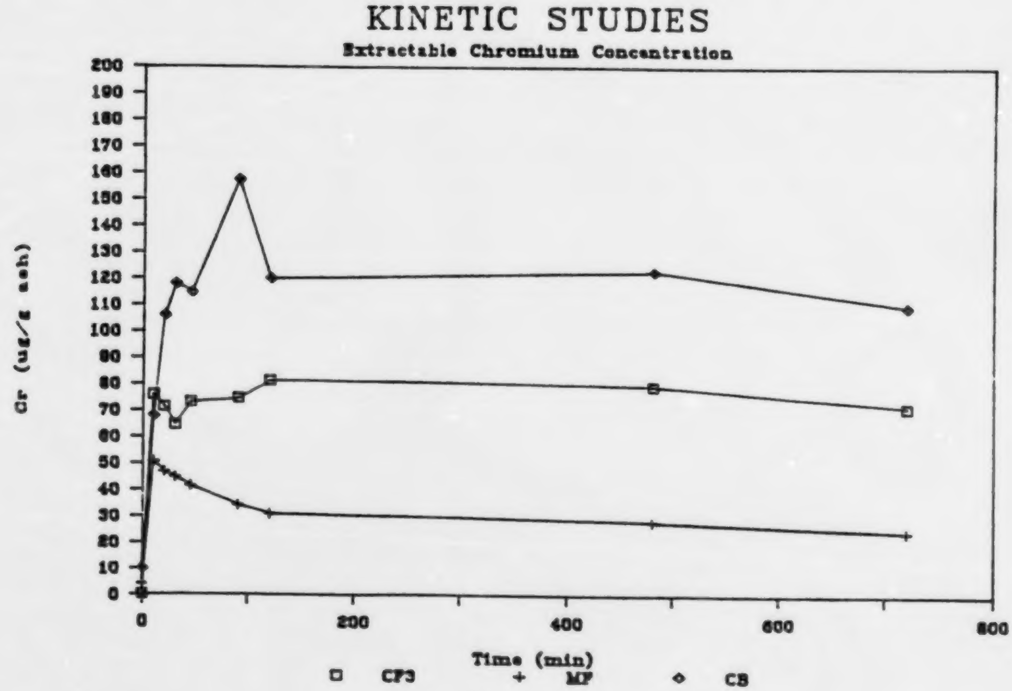


Figure 5

ELECTROCHEMICAL RECOVERY

Electrochemical methods offered the advantage of the recovery of a relatively pure metal in a usable form; whereas precipitation methods generate a flocculent which requires disposal. Electrodeposition of metals does not require the addition of any extraneous compounds to an already complex solution. Cyclic voltammetry was carried out on standards of known metal concentration and compared to the aqueous extracts in order to determine the operating parameters for Pb recovery.

Materials and Methods

Cyclic voltammetric studies were carried out in order to determine the characteristic peak of Pb, and to determine the recoverability of lead from the extract solutions. Standard solutions of 180 mg Pb/L in a 1N NaCl solution (acidified with HCl acid) were prepared. Five grams of ash (dry weight) were extracted with 100 ml of the acidified 1 N NaCl solution. Both the standards and the extractants were subjected to a voltage range of -1.8 to +0.2 volts, a specified scan rate of 50 millivolts/sec, and the current response was recorded. The anode and cathode in these preliminary experiments were both carbon rods. The solutions were analyzed prior to and after experimentation via atomic absorption spectroscopy for the presence of Pb, and the pH was also measured.

Experimental Results

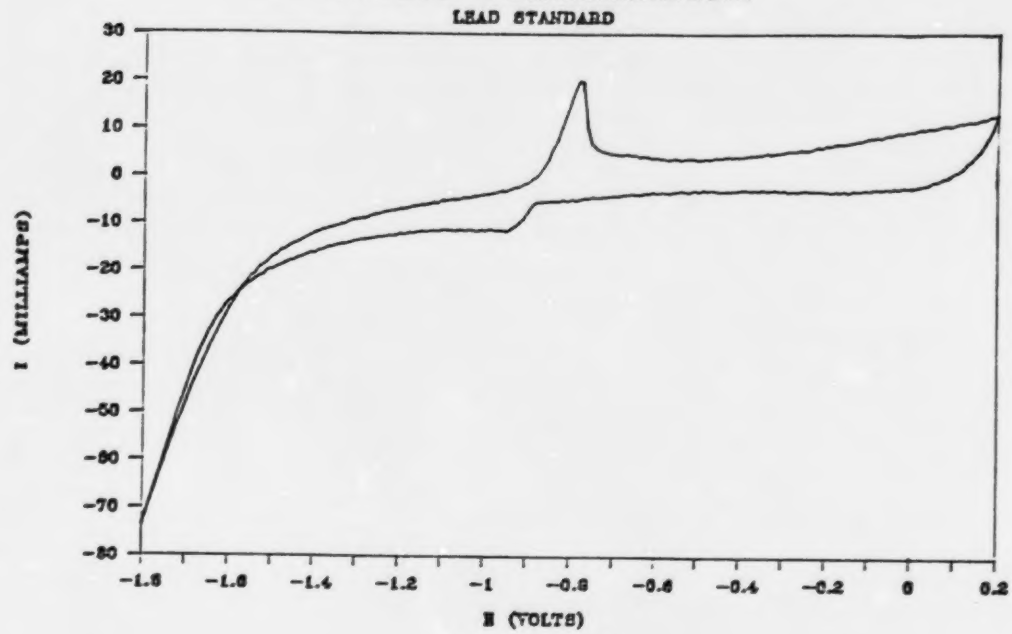
The current response observed for the 180 mg Pb/l standard solution is shown in Figure 6. This cyclic voltammogram reveals a plating potential range of -.95 V to -.70 V for lead in this solution. Cyclic voltammetry was carried out utilizing an extract solution with a pH of 3.0 and a concentration level of 175 mg Pb/l (Figure 7). Results from this cyclic run exhibited a peak within this range, indicating that lead may be plated out of the extract solution.

The presence of a second peak in Figure 7 indicates the occurrence of another process. Identification of the peak is currently underway, and Cd, Fe, Zn, and Cr have already been eliminated as possibilities through comparative cyclic runs of their corresponding standard solutions.

It should be noted that the acidified, 1N NaCl extractant solution was also exposed to a similar voltage range in order to isolate and identify any effects which could be attributed to the solution itself, as opposed to the ash. The voltage curve for the salt solution did not exhibit any additional peaks.

CONCLUSIONS

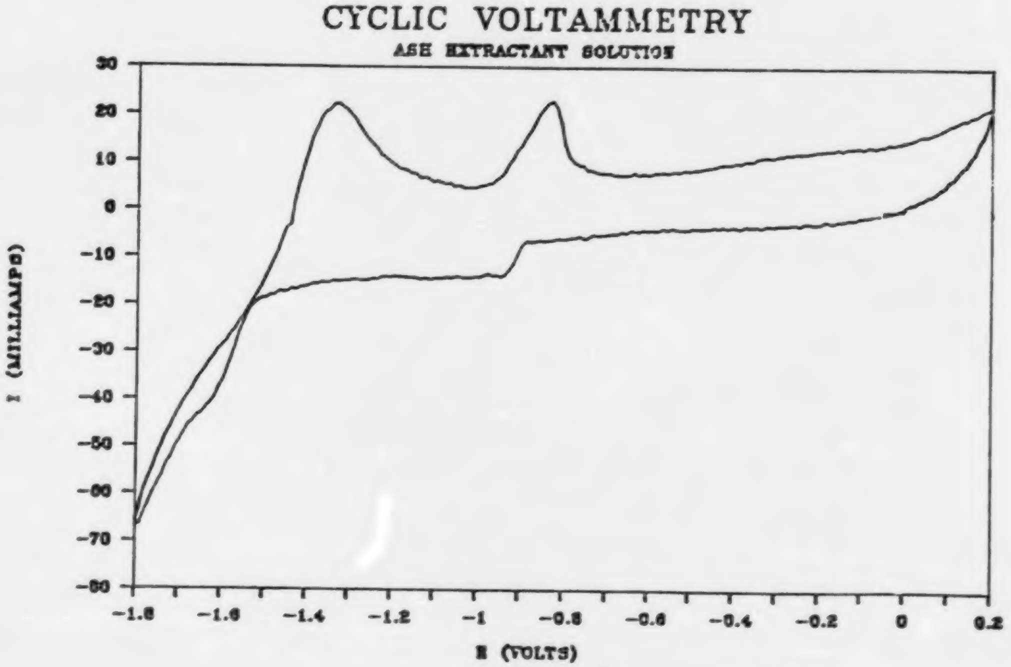
The residual ashes from MSW incineration contain high levels of hazardous metals, and leachable concentrations of these materials often surpass the EP Tox test limits as mandated by the USEPA. The classification of these materials may be considered hazardous, warranting costly landfilling. This led to the investigation of the extraction and recovery of Pb, Cd, Cr from the residual ashes. A series of kinetics experiments



CYCLIC VOLTAMMETRY

LEAD STANDARD

Figure 6



CYCLIC VOLTAMMETRY

ASH EXTRACTANT SOLUTION

Figure 7

were carried out, developing the characteristic extraction trends of the various ashes. The extraction kinetics of CF3 ash exhibited a peak in the lead concentration curve at an unsteady state time period of 10 minutes, indicating that the ash/extractant reaction should be halted at this time period in order to remove a maximum quantity of lead from the ash particle. Optimum extent of reaction, in terms of unsteady state time periods, for the various ashes are 90, 90, 10, and 10 minutes for the CB, MF, MB, and MM ashes, respectively. Cyclic voltammetric experimentation exhibited the potential for metals recovery in a relatively pure form through plating techniques.

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AN INCREMENTAL APPROACH TO THE DEVELOPMENT OF A HAZARDOUS WASTE MANAGEMENT SYSTEM: MANITOBA'S APPROACH AND EXPERIENCE IN THE SITING PROCESS

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The Manitoba Hazardous Waste Management Corporation

1.0 INTRODUCTION

The development of a hazardous waste management facility is no simple task. The process of finding a site and preparing an application is relatively straightforward. However, taking that proposal through the regulatory process to fruition can be a project planner's nightmare. A few examples from the United States help place these comments into perspective.

A total of eighty-one applications for commercial hazardous waste treatment or disposal facilities in twenty-eight States have been submitted since 1980. Of these, thirty-six are still in progress. Fourteen applications have been approved under RCRA however, only six of these have proceeded to become operational facilities (Condron and Sipher, 1987). Many States are currently attempting to gain approval for siting proposals. New Jersey's siting initiatives are stalled in court (Gimello, 1988) and North Carolina recently set attendance records for public meetings. An estimated fifteen thousand residents showed up at separate meetings announcing proposed hazardous waste facility sites (pers comm. A.G. Turner, May, 1988).

The need to develop hazardous waste management capabilities is well recognized in most jurisdictions, including Manitoba. In general, the public acknowledges this need and is supportive of hazardous waste management initiatives. However, as demonstrated in many areas, this so called public support has a tendency to vaporize when a specific site is identified.

The challenge, as we perceive it, is bridging the gap between general public support and real community support. The most crucial step in this process is gaining the trust and support of a local community that will ultimately carry through to facility development and beyond. In Manitoba, this challenge will be met by following a very open, consultative and voluntary site selection process. This paper summarizes the Corporation's approach to site selection along with proposed criteria for the identification and evaluation of potential sites.

2.0 SYSTEM DESCRIPTION

The Province of Manitoba initiated development of a Hazardous and Special Waste Management Program in 1982 in response to increasing environmental awareness and concern regarding the appropriate collection, treatment and disposal of hazardous wastes. The Manitoba Hazardous Waste Management Corporation evolved out of this program and began operation in August, 1987. The Corporation is currently proceeding with studies directed at defining the waste market in Manitoba, review of waste treatment technologies and site selection. The Corporation is pursuing other initiatives and programs aimed at increasing the awareness of waste management options in general, and providing specific services to industry in the areas of waste minimization and technical support.

The proposed Manitoba hazardous waste management system will consist of a central facility supported by a series of regional transfer stations. The central facility will ultimately meet the storage, treatment and disposal requirements for provincially regulated hazardous waste. However, it will be developed on an incremental basis as the need for specific capability and/or technology is justified. Criteria developed for facility siting assume that a fully integrated facility will ultimately include the following components:

- analytical facility;
- centralized storage, materials handling and volume reduction facilities;
- physical/chemical treatment facility;
- organic waste treatment facility such as incineration;
- treatment residue stabilization facility;
- treatment residue repository; and
- supporting infrastructure for the above.

Specific treatment and disposal technologies will be chosen for the facility based on the types and quantities of waste generated in Manitoba and the best available technology giving consideration to capability, technical, environmental and economic performance.

Approximately 20,000 tonnes of hazardous wastes are produced annually in Manitoba, 40 percent of which is generated within the City of Winnipeg (Yee et al., 1985). Class 8 wastes (corrosives) dominate, accounting for approximately 75 percent of total waste generation reported. At the time this survey was completed, approximately 75 percent of the wastes were either disposed of through the sewer system or placed in landfills. This information is currently being updated to provide more direction to the selection of appropriate treatment technologies to meet provincial needs.

Transfer stations will be added to the system as the need is justified. They will be relatively small, consisting primarily of a warehouse/office building and associated materials handling facilities. Transfer stations will function as the "door to the system" and will be developed to meet regional hazardous waste management requirements. Figure 1 shows an artist's impression of a fully integrated hazardous waste management facility and a commercial scale transfer station.

The initial development proposal, consisting primarily of storage and minimal treatment capability, is scheduled for submission by the end of 1989. Facility construction is scheduled to commence in early 1990 and initial operation of the basic system will commence in 1991. Additional technologies will be added as required with a fully integrated capability being possible as early as 1993.

3.0 SITE SELECTION PROCESS

The Corporation has prepared a discussion document outlining the proposed process for the selection of potential sites for facilities development (Latonas, 1988). This document has been distributed to a wide range of potential stakeholders for review and comment. The proposed process is dynamic and incorporates elements of local responsibility and "co-management", particularly in the selection of potential sites.

3.1 Objectives

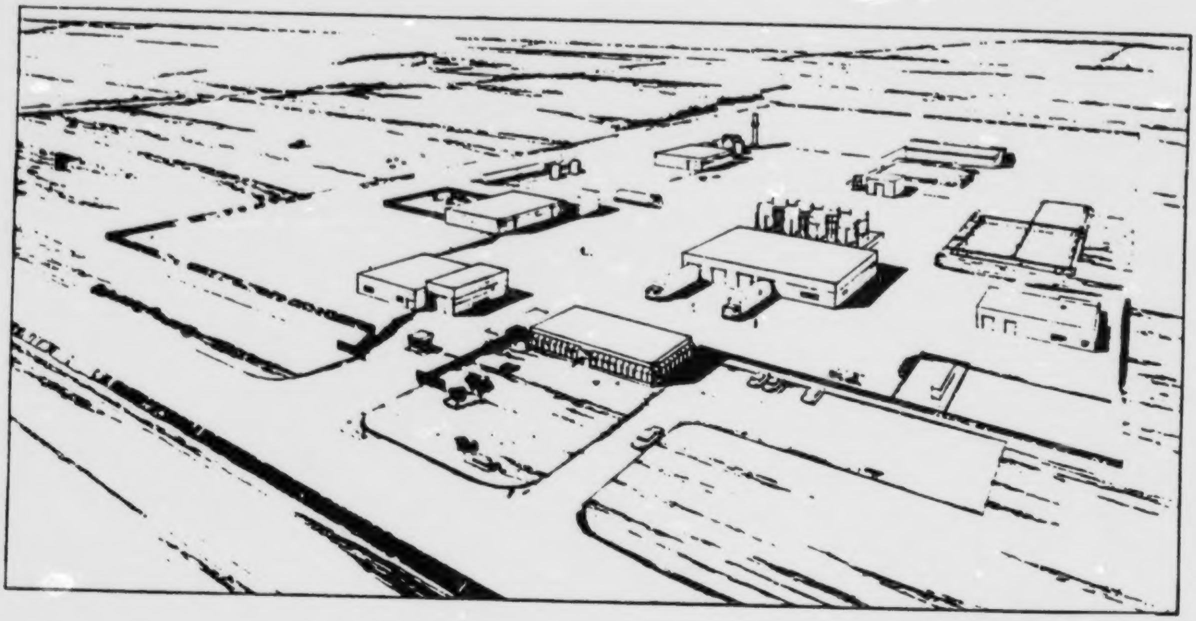
The specific objectives of the site selection process are to:

- identify technically and economically feasible sites which are environmentally acceptable and will ensure protection of public health and safety; and
- seek and respond to public concern and input, both provincially and locally, in order to obtain support for the system's development in general, and local public support for site alternatives in particular.

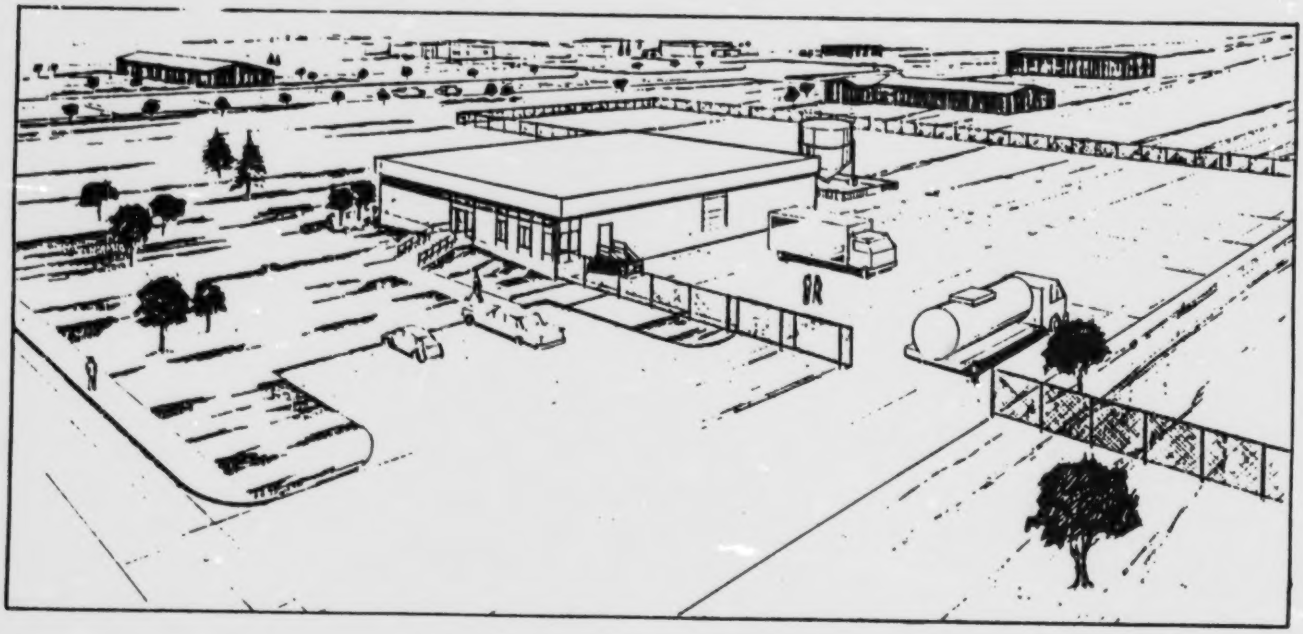
These objectives recognize the need to incorporate and integrate environmental, technical, economic, and social criteria in the search for candidate sites.

3.2 Proposed Site Selection Process

Experience elsewhere in North America demonstrates that there is no "formula" which can guarantee the successful siting of a hazardous waste management facility. The process can be extremely lengthy, expensive and unsuccessful if not conducted thoroughly and within an open public forum. Furthermore, it is impossible to prejudge the situation and anticipate all potential concerns to be met in the siting process. Therefore, it is essential that the process be flexible, evolutionary and incorporate a proactive public and stakeholder participation component. Ultimately, it is "public acceptance" which constitutes the dominant factor in successfully siting a hazardous waste management facility.



Fully Integrated Central Facility



Commercial Transfer Station

Figure 1 Hazardous Waste Management Facilities

The proposed site selection process incorporates the experience gained from examining siting programs in other jurisdictions and the recommendations of the CEC (1987) derived through public hearings. Site selection for the Manitoba Hazardous Waste Management System will be conducted in phases as described below (Figure 2).

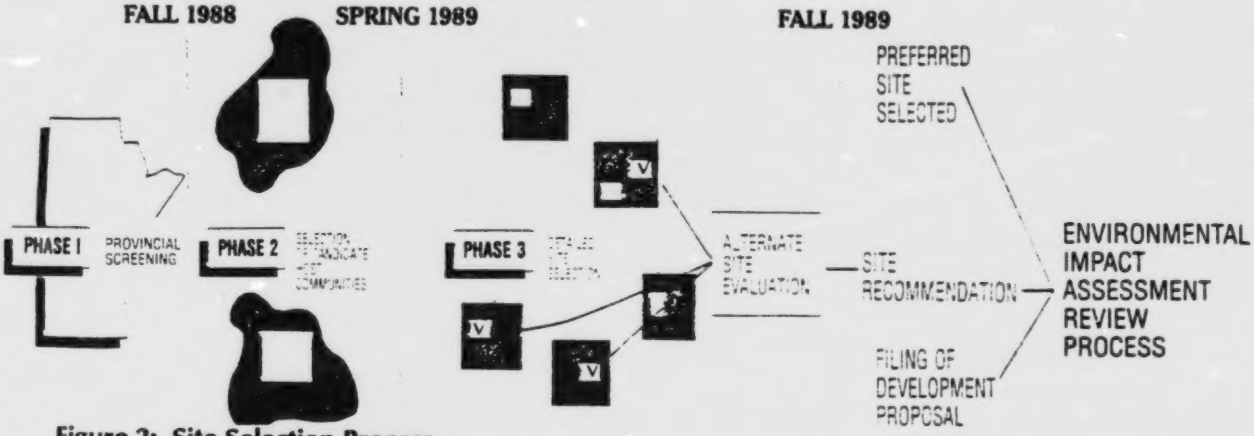

FALL 1988
SPRING 1989
FALL 1989
PHASE I
PROVINCIAL SCREENING
PHASE 2
SELECTION OF CANDIDATE HOST COMMUNITIES
PHASE 3
DETAILED SITE SELECTION
V
ALTERNATE SITE EVALUATION
PREFERRED SITE SELECTED
SITE RECOMMENDATION
FILING OF DEVELOPMENT PROPOSAL
ENVIRONMENTAL IMPACT ASSESSMENT REVIEW PROCESS

Figure 2: Site Selection Process

3.2.1 Phase 1: Site Selection Process and Criteria Development

The overall intent of Phase 1 is to lay the initial planning framework for activities related to site selection. Phase 1 is currently in progress and deals at the provincial level. Discussion documents on the proposed site selection process and siting criteria have been prepared for public comment in Phase 1 (Latonas, 1988 and Latonas and Kucera, 1988). General response to the Corporation's discussion documents will be incorporated into the process so that it better reflects the needs, concerns and expectations of all potential stakeholders.

A major output of the Phase 1 work included the preparation of a series of provincial maps identifying regions with significant constraints to facility siting (excluded areas). In order to provide as much direction as possible at this early stage of the process, those areas with the greatest potential to accommodate siting (Acceptable regions) were also identified. Future site selection initiatives will focus on these regions.

3.2.2 Phase 2: Selection of Candidate Host Communities

Phase 2 of the process is directed towards identifying candidate host communities. Information used in the selection of acceptable regions (provincial screening results) will be verified and more detailed information on these areas will be compiled. Local information sessions will be sponsored to provide community leaders and the general public with more detailed information on the site selection process and the subject in general. The objective of this step is to work at the community level to identify potential interest and/or support for facility development and concerns associated with it.

The final step in the Phase 2 program is the selection of host communities. Those communities which meet the technical screening criteria and demonstrate continuing public support for the project will be invited to register as a host community. It should be noted that no absolute commitment of support is required from a community at this stage. All candidate host communities are entitled to review all information pertaining to the development (site specific information in particular, prior to committing support for the project. Participation in the program is completely voluntary and communities are free to withdraw from further consideration at any time.

Those not selected, and those eliminated at earlier stages, may be evaluated as potential sites for transfer stations. A similar open and consultative process will be followed to select optimal locations for transfer stations.

3.2.3 Phase 3: Site Selection and Evaluation

The Phase 3 process includes the identification and ranking of site alternatives within host communities. The first step in this process will be defining community boundaries and establishing a Community Advisory Committee in each. The Community Advisory Committees will have the responsibility of representing the public interest in future facility planning decisions and will be encouraged to take an active part in all future public open houses and meetings. These Committees will be determined locally and will constitute the first step in establishing an element of "co-management" in the Corporations facilities development activities.

The Advisory Committees will develop detailed community-specific site selection criteria in consultation with the Corporation. Workshops will be held to further refine proposed criteria and develop weighting factors to be applied in their area. Siting criteria and weighting factors developed through this process will include location sensitive technical, environmental, and land use factors only. Corporation staff will use these criteria to identify potential candidate sites within each host community and results will be presented to the Advisory Committees and the public prior to finalization.

Specific information requirements will be identified and detailed site investigations will be conducted on potential sites identified within each community. Site investigations will include on-site surveys (eg. hydrogeological studies) to provide the level of detail required to make professional judgements with respect to relative site suitability for facility development. Results of detailed site investigations will be presented to the public and reviewed in detail with Advisory Committees prior to the final selection of the preferred site alternatives.

At this stage of project planning it is important that host communities provide a final declaration of public and community support. The Corporation will work through the Community Advisory Committees and local government councils to achieve this goal.

3.4 Final Site Selection and Regulatory Applications

This process will make it possible to identify and rank a set of alternate sites, all of which may offer acceptable development alternatives. The criteria and ranking system developed in consultation with Advisory Committees will provide the basis for ranking of sites on technical, environmental and land use merits. The Corporation will use this information in making its final site selection. Other considerations such as economics and judgement on the maintenance of public support will be incorporated into the Corporation's business decision in finalizing the recommendations that it puts forward in its formal development proposal.

A recommendation will be made by the Corporation to its Board of Directors to submit a proposal to the Director of Manitoba Environment & Workplace Safety & Health, pursuant to The Dangerous Goods Handling and Transportation Act, for the development of a hazardous waste management facility at the preferred site. An alternate site(s), which meets all of the technical criteria, will also be identified if possible. This development proposal will outline details of the proposed facility and provide documentation of the site selection process. Although this application does not fall directly under the jurisdiction of The Environment Act, the process outlined in that Act for the preparation and review of an Environmental Impact Assessment is expected to be followed.

4.0 SITE SELECTION CRITERIA

The Corporation is of the opinion that there is no single best site for facility development because this judgement will vary considerably between individuals. Alternatively, there are potentially numerous sites which could be considered acceptable for facility development provided that certain technical, environmental and land use criteria are met. Therefore, the approach adopted by the Corporation is geared towards defining the characteristics of an acceptable site through the development and application of siting criteria.

A discussion document on the siting of hazardous waste storage, transfer, treatment and disposal facilities in Manitoba was prepared to present proposed technical, environmental and land use criteria to the public (Latonas and Kucera, 1988). The report is intended to stimulate public discussion on issues related to facility siting.

Three sets of criteria are proposed as outlined below:

- Provincial Screening Criteria include natural hazard, environmental, technical and land use criteria which, when applied on a province-wide basis, eliminate large areas where the probability of finding suitable facility sites is low.

- Regional Site Selection Criteria represent detailed technical, environmental and land use criteria for the identification and evaluation of potential sites for a fully integrated hazardous waste management facility. These criteria will be applied in "acceptable regions" as identified through the provincial screening process.

- Transfer Station Site Selection Criteria address those siting issues pertinent to the location of regional transfer stations.

4.1 Provincial Screening

The provincial screening process was developed to provide an efficient means of identifying potentially acceptable regions of the province for siting an integrated hazardous waste management facility. It is the first step in the site selection process and is, in essence, the qualification of regions where the probability of finding sites which will meet the more detailed regional site selection criteria is maximized.

This is achieved by applying provincial "exclusion" criteria to eliminate areas which exhibit significant constraints to facility siting. Provincial screening criteria were developed to identify:

- areas where natural hazards pose an unacceptable risk to facility integrity;
- areas which do not provide for the natural protection of the environment; and
- areas where facility development is not technically feasible.

Criteria were developed in four general categories as shown in Table 1.

TABLE 1
PROVINCIAL SCREENING CRITERIA

CATEGORY	EXCLUSION CRITERIA
Natural Hazard	100-year flood plains Seismic risk areas Karst terrain
Environmental Protection	Groundwater pollution hazard areas Provincial parks Wetlands Class 1 agricultural lands Ecological reserves and wildlife lands
Technical	Bedrock outcrop areas Permafrost areas
Land Use	Federal lands

These provincial exclusion criteria were mapped from existing published information using a computerized geographical information system. Those areas not excluded through the application of these criteria are considered to be relatively free of siting constraints at this level. Figure 3 presents a general indication of those areas where significant constraints exist. It does not absolutely exclude these regions from consideration. More detailed analysis within these regions could potentially identify constraint free areas not found at the provincial level. Figure 1 does, however, focus attention on those areas where the probability of finding acceptable sites is greatest.

4.2 Site Selection Criteria: Central Facility

This section presents detailed criteria to assist in the identification and evaluation of potentially acceptable sites. It is stressed that these are proposed criteria only. The Corporation recognizes the need to incorporate public concerns and opinions in the site selection process. Therefore, these criteria are open to review and comment throughout the process and will only be finalized and applied with the support of community-selected Advisory Committees in areas where the Corporation has been invited to pursue the detailed search for potential sites.

These criteria were developed on the premise that engineering design and controls would not be solely relied upon to minimize the probability and/or consequence of an uncontrolled contaminant release at the site, however unlikely that may be. Therefore, a main focus of the criteria is to provide natural barriers to the transport of contaminants via environmental pathways. In addition, it is recognized that certain land uses are not compatible with this type of industrial development. Therefore, criteria dealing with land use issues are also proposed.

The criteria differ in their overall importance to facility siting. The following four categories of criteria are proposed:

- Essential criteria define required site characteristics; areas which do not meet the essential criteria will be eliminated from further consideration.
- Unacceptable criteria identify site characteristics which are considered incompatible with facility development; areas with unacceptable characteristics will be excluded from consideration in the site selection process.
- Desirable criteria define site characteristics which are preferred, but not essential; areas exhibiting desirable characteristics will be given preference over those which do not.

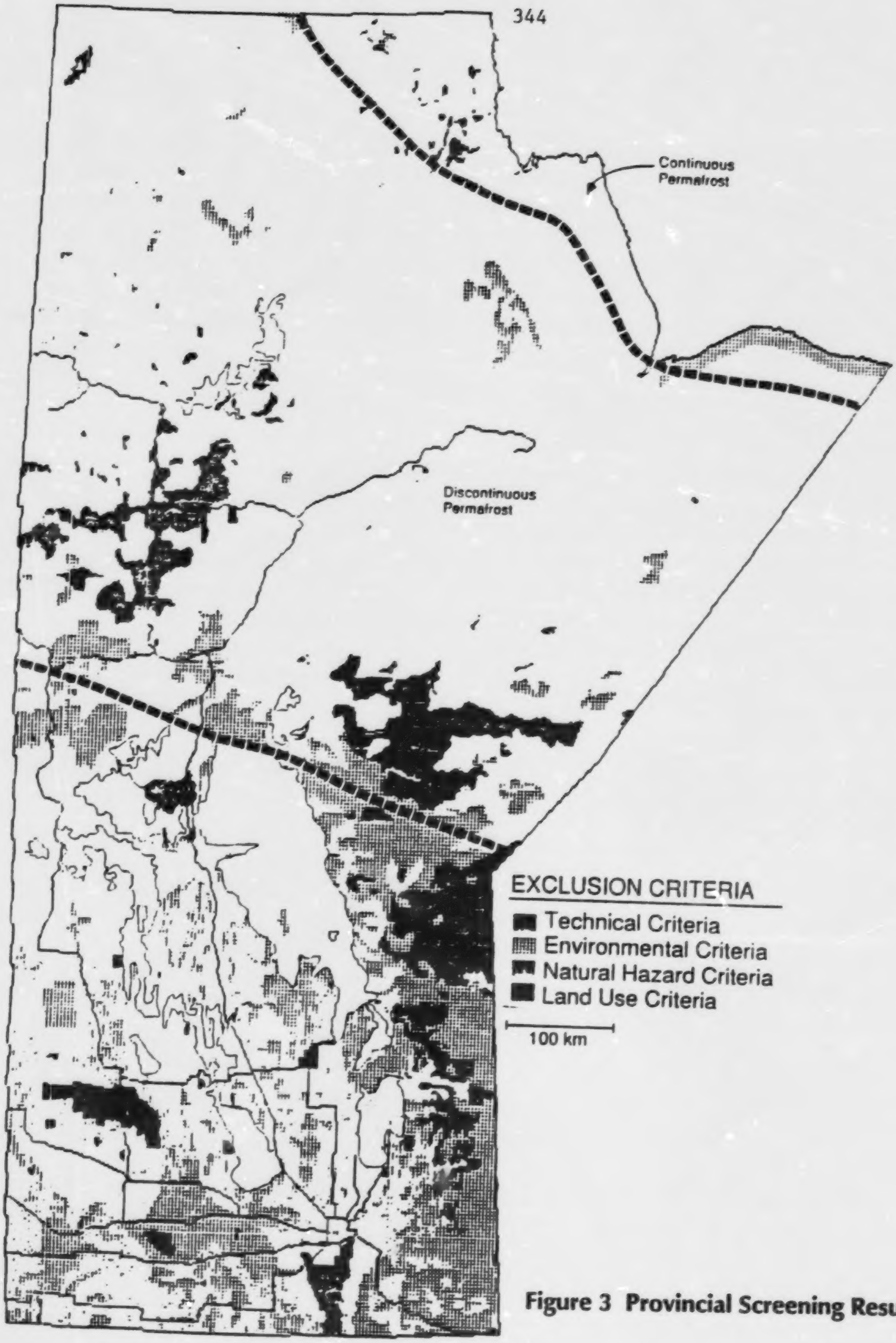

Continuous Permafrost
Discontinuous Permafrost
EXCLUSION CRITERIA
■ Technical Criteria
▨ Environmental Criteria
■ Natural Hazard Criteria
■ Land Use Criteria
100 km

Figure 3 Provincial Screening Results

- o Undesirable criteria define site characteristics which are undesirable but not unacceptable; areas with these characteristics will be given a lower priority in the site selection process.

Tables 2, 3 and 4 summarize the proposed technical, environmental and land use criteria, respectively. Criteria classified as either "essential" or "unacceptable" are exclusionary. Areas which do not meet an essential criterion, or which exhibit an unacceptable characteristic will be excluded from consideration. Absence or presence of "desirable" and "undesirable" criteria will not rule out any areas. However, those criteria can help to evaluate the relative suitability of alternate sites. They may also dictate incremental mitigative and design measures, thereby influencing economic considerations in any final evaluations.

The proposed central facility site selection criteria were prepared following review of siting requirements in other jurisdictions. In addition, they incorporate the response to the Clean Environment Commission (1987) hearings on hazardous waste management issues in Manitoba, particularly public comments concerning on the siting issue. A review of this information is provided in the Corporation's discussion documents.

TABLE 2
PROPOSED CENTRAL FACILITY SITING CRITERIA
Technical Considerations

Component	Criteria	Classification	Justification
Access	Accessible by highway	Essential	Necessary for facility operation
	Accessible by rail	Desirable	Increases flexibility of operation
Services	Regional availability of electric power natural gas, and water	Essential	Required for facility operation
Land Requirement	65 hectares (160 acres)	Essential	Required for facility operation
	Crown land	Desirable	Land use control

TABLE 3
PROPOSED CENTRAL FACILITY SITING CRITERIA
Physical and Environmental Criteria

Component	Criteria	Classification	Justification
Geology	Karst terrain	Unacceptable	Facility integrity
	Seismic prone areas	Unacceptable	Facility integrity
Surficial Geology and Topography	Clay or till of sufficient thickness and low permeability to meet groundwater protection criteria	Essential	Protection of groundwater quality
	Unstable terrain	Unacceptable	Facility integrity
	Steeply rolling terrain	Undesirable	Minimize surface water runoff
Surface Water	100-year flood plains	Unacceptable	Protection of facility integrity/ surface water quality
	Within 500 metres of lakes and continuously flowing streams or rivers	Undesirable	Protection of surface water quality
	Provincially designated exceptional value watersheds	Undesirable	Protection of surface water quality
	Defined watersheds directly feeding reservoirs used for public water supplies	Unacceptable	Protection of surface water quality
Ground Water	Unconfined aquifers (ground water pollution hazard areas)	Unacceptable	High pollution hazard
	5 m of clay/till base with a bulk hydraulic conductivity of 10^{-7} cm/sec or less	Essential	Protection of groundwater quality
	10 m of clay/till base with a bulk hydraulic conductivity of 10^{-7} cm/sec or less	Desirable	Protection of groundwater quality
	TOT_{100} greater than 100 years	Desirable	Protection of groundwater quality
Wetlands	Wetland areas	Unacceptable	Protection of wetland habitat
Climate and Air Quality	Within 1 kilometre of residential zoned land in cities, towns and villages	Unacceptable	Minimization of risk
	Minimum population density in predominant downwind directions	Desirable	Minimization of risk

TABLE 4

PROPOSED CENTRAL FACILITY SITING CRITERIA

Land Use Criteria

Component	Criteria	Classification	Justification
Urban Centres	Within 50 kilometres of a town	Desirable	Facility access and servicing
	Within 100 kilometres of a city	Desirable	Facility access and servicing
Public and Private Facilities	Within 200 metres of a private residence	Unacceptable	Minimization of risk
	Within 1000 metres of public facilities	Unacceptable	Minimization of risk
	Minimum population density in vicinity	Desirable	Minimization of risk and future land use control
Parks	Existing or proposed federal, provincial or municipal parks	Unacceptable	Protection and preservation of parkland
Heritage Resources	Designated or proposed heritage resources	Unacceptable	Protection of heritage resources
Land Claims	Registered native land claims	Undesirable	Land use conflict
Renewable Resource Land Use			
Agriculture	Class 1 agricultural lands	Unacceptable	Protection of inherent agricultural capability
	Class 2 and 3 agricultural lands	Undesirable	Minimize conflict with agricultural production
	Intensive agricultural land uses	Undesirable	Minimization of risk and land use conflict
Forestry	Within a designated seed orchard	Unacceptable	Protection of key forest production lands
	Class 2 and 3 forestry lands	Undesirable	Protection of high productivity forestry lands

Table 4 (continued)

Component	Criteria	Classification	Justification
Fisheries	Provincially designated high quality watersheds	Undesirable	Protection of surface water quality
Wildlife	Designated wildlife management areas or wildlife refuges	Unacceptable	Protection of key wildlife habitat
	Class 1 wildlife lands	Undesirable	Protection of key wildlife habitat
Ecological Reserves	Within an existing or proposed Ecological Reserve	Unacceptable	Protection of ecologically significant areas of the province
Mining	Active and inactive mining areas	Unacceptable	Land use conflict and facility integrity
Proposed Development Areas	Designated Reservoir Areas and Power Reserves	Unacceptable	Minimize future land use conflict
	Designated development reserves and active proposal areas	Undesirable	Minimize land use conflict

4.3 Site Selection Criteria: Transfer Stations

Transfer stations will be required to provide an equitable and cost effective service to all provincial generators. Therefore, they must be strategically located giving consideration to the provincial distribution of waste generation.

Transfer stations will function to receive, package, store and convey hazardous wastes to the Corporation's central facility. They will be licensed as Regional Collection Facilities under the Dangerous Goods Handling and Transportation Act. As such, they will not normally accumulate large quantities of wastes or store wastes for periods greater than 90 days. The facilities will be relatively compact and resemble, in general appearance, a traditional warehouse operation.

Transfer stations will be sited ideally within, or adjacent to, existing urban centres to ensure accessibility and proximity to potential markets. It is not necessary to achieve the same level of secondary environmental containment as is considered appropriate for the central facility site, since their operation will not involve treatment or residue disposal. Therefore, the proposed criteria allow greater flexibility for the application of engineering solutions in lieu of natural barriers to contaminant transport.

Tables 5, 6 and 7 present the proposed technical, environmental and land use criteria considered appropriate for siting transfer stations. Criteria are classified as "essential", "desirable", "unacceptable" or "undesirable" consistent with the proposed regional site selection criteria. Justification is also provided for the inclusion of each criterion.

TABLE 5
PROPOSED TRANSFER STATION SITING CRITERIA
Technical Considerations

Component	Criteria	Classification	Justification
Access	Accessible by Highway	Essential	Necessary for facility operation
	Accessible by rail	Desirable	Increases flexibility of operation
Services	Local availability of essential services	Essential	Necessary for facility operation
Land Requirement	1.6 ha minimum	Essential	Minimum lot size to accommodate stand-alone facility

TABLE 6
PROPOSED TRANSFER STATION SITING CRITERIA
Physical and Environmental Criteria

Component	Criteria	Classification	Justification
Geology/ Surficial Geology	Unstable terrain	Unacceptable	Facility integrity
Ground Water	Unconfined aquifers	Undesirable	High pollution hazard
	Clay/till base with a bulk hydraulic conductivity of 10^{-7} cm/sec or less	Desirable	Protection of groundwater quality
Surface Water	100-year flood plain	Unacceptable	Protection of facility integrity/ surface water quality
	Within 200 m of lakes and continuously flowing streams and rivers	Unacceptable	Protection of surface water quality
Climate and Air Quality	Minimum population density in predominant downwind direction	Desirable	Minimization of risk

TABLE 7

PROPOSED TRANSFER STATION SITING CRITERIA
Land Use Criteria

Component	Criteria	Classification	Justification
Zoning	Industrial zoned land	Essential	Compatibility with existing land use
	Designated or discretionary use under existing land use By-law	Essential	Compatibility with existing land use
Private and Public Facilities	200m from residential zoned land and 500m from public facilities	Essential	Minimize land use conflicts and public perception of impact

4.4 Regions of Greatest Interest

It is obvious that not all "constraint free" areas identified through the provincial screening process (Figure 3) will meet the detailed requirements of an acceptable site as proposed in the site selection criteria. Therefore, evaluation of these criteria on a provincial basis is warranted to provide more direction to the next phase of site selection.

Of the "essential" criteria proposed for the central facility site, only those related to surficial geology are suitable for site screening on a provincial basis. The most important criteria in defining suitable areas are those related to the thickness and type of surficial materials. In order to identify those non-excluded regions having the best surficial geology, the following "inclusion criteria" have been mapped:

- regions underlain by clay, glacial till or a combination of the two; and
- clay and till deposits 10 metres or greater in thickness.

When applied in combination with the provincial screening results, these criteria identify regions with significant potential to meet all siting requirements.

Figure 4 shows only those areas which are free of the provincial screening constraints and have the desired surficial deposits. Based on the results of this work, the greatest potential to meet the technical and environmental site requirements are in those areas identified in Figure 4. Detailed information was not available for northern Manitoba and therefore, consistent results for the entire province cannot be presented. This lack of detailed information along with general concerns such as permafrost represent significant constraints to siting in the north.

The province has been painted with a "broad brush" in this process and the results should be interpreted with some caution. Potentially acceptable areas may have been inadvertently eliminated either through the provincial screening process or because of limitations regarding detailed information for the inclusion criteria. However, these results focus our attention on those areas where the potential to find acceptable sites is considered greatest.

5.0 SUMMARY

The proposed site selection process provides a logical planning process for the identification and evaluation of potential sites. It provides considerable opportunity for public involvement and includes local input through the Community Advisory Committees in the site selection decision making process. Public participation and consultation programs will first be conducted province-wide, but will eventually be directed at regions with significant potential. It is anticipated that the concept of "co-management" will be extended to the development and operation phases of the project.

The provincial screening results have identified those regions of the province with the greatest potential to meet the siting requirements of this project. This information, along with the proposed siting criteria, is available to communities to assist them in understanding project requirements. The proposed criteria and public response to consultation on them will form the basis for development of specific criteria to be applied in host communities. Finally, the process is voluntary and communities are free to withdraw from the process at any time.

The Corporation has essentially completed Phase 1 of its site selection process. Public information prepared in support of its activities will be widely distributed and presented for comment at a series of open houses. These are scheduled to commence immediately; the Corporation is sponsoring fourteen open houses around the province in November. The Corporation will continue to respond to all inquiries related to facilities development and additional open houses will be organized in any community wishing to learn more about our activities or hazardous waste management in general.

The siting of hazardous waste management facilities is not an easy task. It is hoped that this voluntary approach, coupled with an open exchange of information, will provide the necessary forum to meet both the community's and the Corporation's objectives.

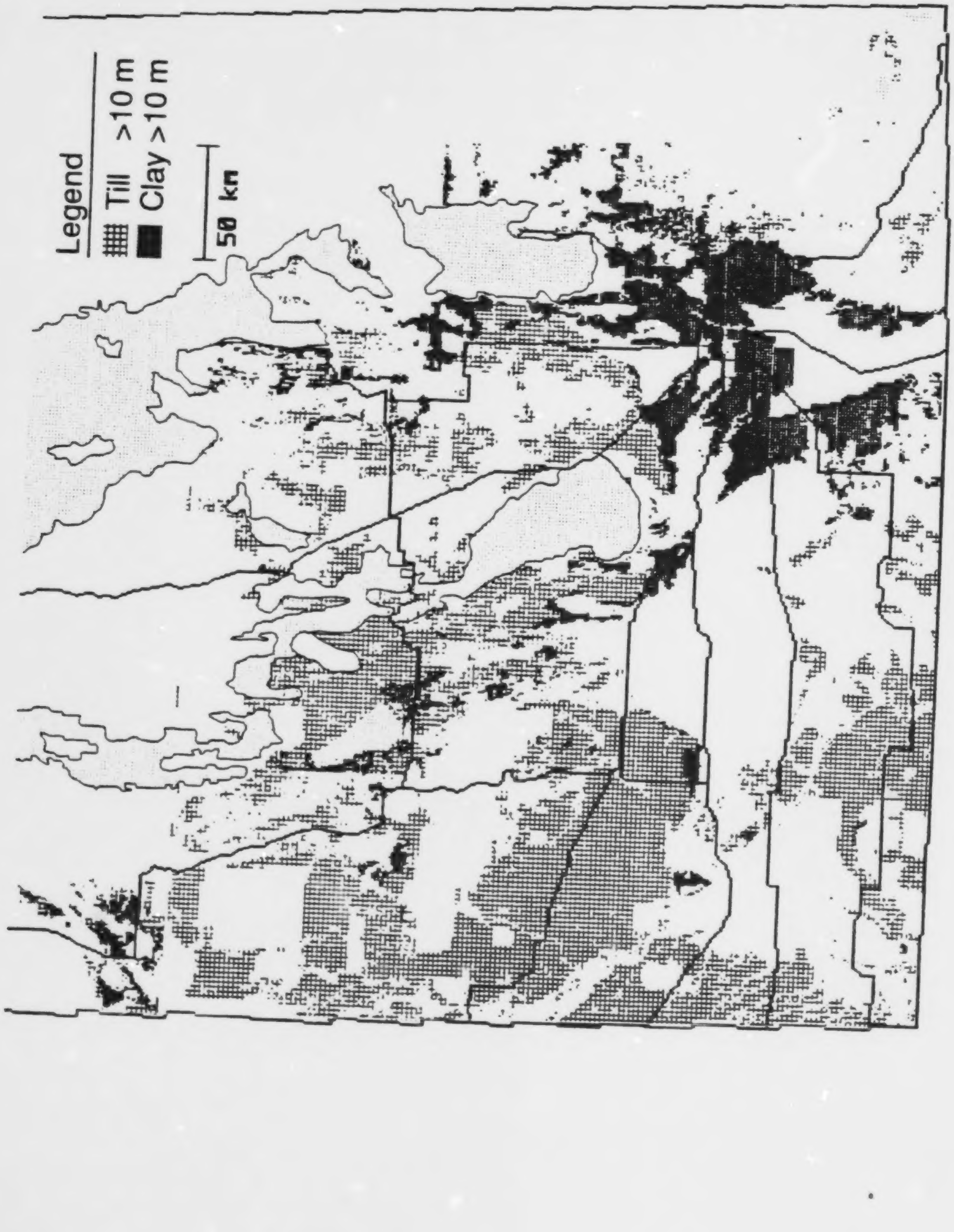

Legend
▦ Till >10 m
■ Clay >10 m
50 km

Figure 4 Regions of Greatest Interest

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THE SIGNIFICANCE OF PROPERTY VALUE GUARANTEES AS A TOOL FOR SITING WASTE DISPOSAL FACILITIES

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ABSTRACT

Property value guarantees may be an effective tool in siting waste facilities if property values accurately reflect facility impacts or if residents believe property values result from facility impacts.

A review of numerous empirical property value studies shows inconsistent results. Physical impact analyses and property value differential analyses are carried out at two typical waste facilities, a landfill and an incinerator. No significant effects of observed physical impacts on property sales prices are present. Property value effects are therefore shown to be inadequate indicators for facility impacts or host community opposition. Hence, if property value guarantees are effective in gaining host community acceptance, it is because they address fears about facility impacts rather than objectively measurable property value losses.

Representative surveys are conducted among residents of host and control communities at a landfill and an incinerator site to test whether property value impacts were believed to be significant and to determine the effectiveness of property value guarantees on facility acceptance.

Although property value losses are a significant concern, 50% of the respondents do not consider property value guarantees fair compensation for hosting an intolerable waste facility. Moreover, property value guarantees are significantly less acceptable among concerned residents than among less concerned people at a new incinerator site. Therefore, property value guarantees are not very effective in addressing residents' concerns about a waste facility impacts to gain acceptance. An alternative approach is derived to identify and reduce the cause for specific impacts in kind and as close as possible to the waste generating source.

INTRODUCTION

Property value depreciation is often one of the reasons for host community opposition to waste disposal facility siting. In theory, property value differences will reflect the facility impacts that are perceived to deteriorate residential quality in the host community (Freeman, 1979).

If this is true, then facility proponents could gain acceptance in the host community by guaranteeing property values for affected owners. The significance of property value guarantees as a siting tool to gain host community acceptance depends on two questions:

1. Are waste facility impacts accurately reflected in residential property value differences? The answer to this question determines if property value guarantees are an appropriate method to address facility impacts on a simple, market value (i.e., dollar) scale.
2. Do property value guarantees (PVG) address a negative perception about facility impacts on host communities? If residents are convinced that waste

facilities cause property value losses, then PVG may be an effective way of increasing facility acceptance in the host community regardless if property value losses actually occur.

The effects of waste facilities on property values are tested in three steps. First, the empirical results of property value studies in the literature are analyzed. Then, detailed physical impact analyses and property value studies are carried out at two typical municipal solid waste disposal facilities, a landfill and an incinerator. Finally, the effectiveness of property value guarantees is tested with opinion surveys of host and control community residents.

EMPIRICAL EVIDENCE OF NOXIOUS FACILITY IMPACTS ON PROPERTY VALUES

A waste facility's physical, social and political impacts will affect residential property values if the impacts are perceived to detract from the residential enjoyment (Freeman, 1979). Thus, both physical and non-physical impacts (e.g., impage of the community) alike can affect property values as long as they are perceived by the average buyer. Property value differences should, therefore, summarily reflect all perceived impacts caused by the facility.

Property Value Studies at Noxious Facilities

(a) Waste Disposal Facilities

- Havlicek, Richardson and Davies (1972, in Schmalensee, 1975) used distance and angle from the downwind direction from landfills as dependent variables on MLS (Multiple Listing Service) sales prices to achieve a total explanation of price variation of 79% at significant correlation. Thus, distance from the facilities had a significant effect on property values.
- Goldberg (1972, in Schmalensee, 1975) tested distance and visibility as variables to explain the variation as percentage change (i.e., the rate of change) in property values over time at landfills. The results were insignificant.
- Schmalensee et al. (1975) studied properties around four landfills in California and found only marginally significant correlation between distance and property sales prices. No significant effect on appreciation or residential development near the site was observed.
- Hockman et al. (1976) studied 55 landfills and 15 incinerator sites in Chicago SMSA using distance and angle from the predominant downwind direction to estimate property sales prices. The results were significant and indicated impacts of landfills extending over three city blocks, equivalent to 6 to 7 cents per ton. Incinerator effects extended 20 city blocks and amounted to $1.70 per ton.
- Groth (1981) studied the effects of five landfills in California, Oregon and Washington on property values, appreciation rates, land-use patterns, and rents. Very few and only marginally significant effects were observed.
- Baker (1982) regressed market prices on linear, logarithmic and square root transformations of distance to two landfills for domestic solid waste and one industrial waste landfill in New York State. The results show some significant effect of distance, particularly after 1978 (Love Canal) at the industrial (and hazardous) waste site. The property value effects at the municipal waste landfill were insignificant.
- Zeiss (1984a) regressed market prices on distance from the landfill and

access road of the Premier Street Landfill in North Vancouver, B.C. The results showed a 7% to 20% increase in prices between 120 and 1500 metres (400 and 1,970 feet) distance from the site.

- Gamble and Downing (1984) found significantly lower property values near landfills as compared with control areas. The effects were confirmed in a correcty specified hedonic price model only for those parcels on the main access road, where a statistically significant effect was found.
- Price (1987) studied 6 waste-to-energy plants, 3 transfer stations and 3 landfills by comparing sales prices, rents, new development activity in host communities and comparable locations. None of the solid waste management facilities were found to cause residential property values to decline.

(b) Other Undesirable Facilities

Studies of similar or possibly more noxious or risky facilities show ambiguous results:

- Blomquist (1974) found significant correlation of property value differentials within 3 kilometres (1.9 miles) of the Winnetka electrical utility power plant in Illinois. The differentials were best fitted by a linear function with a 0.9% price decline for every 10% decrease in distance from the plant.
- Nelson (1981) studied the sales prices before and after the Three Mile Island accident and found no significant price or appreciation rate differences within a 32 kilometre (20 miles) radius of the plant. However, other possible explanations for the lack of effects were identified (short observation period, expectation of government assistance, absence of actual physical damage, influx of clean-up workers).
- Gamble and Downing (1982) studied property sales around four nuclear power plants in the northeastern U.S. Plant visibility and distance were regressed on the property values of 583 single family dwelling sales in a 25 mile radius from the Three Mile Island site and 112 sales in a control area. No significant effects were found.

Summary of Empirical Evidence

The reported results show no consistently significant waste facility impacts on residential property values. The results of studies at nuclear power plants are particularly puzzling, because they show no property value effects at facilities that are perceived to be very risky (Slovic et al., 1985). Moreover, the lack of significant property value results does not correlate with the level of expected (and experienced) host community opposition at all types of facilities that were studied.

Apart from some methodological problems, none of the studies used correctly measured physical impacts, but instead, relied on distance and angle from downward direction to indicate exposure to facility impacts.

The following study was undertaken so that a property value relationship could be determined based on real impacts.

PHYSICAL IMPACT ASSESSMENT AND PROPERTY VALUES AT TYPICAL LANDFILL AND INCINERATOR FACILITIES

Site Selection and Description

Two typical waste facilities, a landfill and an incinerator, were selected by conducting a written facility survey and personal site visits of waste facilities in the Provinces of Alberta, British Columbia, Manitoba and Saskatchewan and the states of Oregon and Washington. The selected landfill best represent typical characteristics of 25 sites; the selected incinerator was the only modern mass burning grate incinerator in operation in late 1986 (Zeiss, 1988).

Landfill. The Tacoma City landfill facility comprises 81 hectares (200 acres) on the western boundary of the City of Tacoma. Since fill operations began in 1960, some 3.15 million tonnes of refuse have been deposited in cells of 6 to 21 metres (20 to 70 feet) depth. Presently, the landfill accepts approximately 171,000 tonnes per annum of refuse generated by 160,000 residents in the city and 52,000 residents in smaller, neighboring communities. The expected life is five to six years at current waste volumes (Black and Veatch, 1987).

The host community consists of three distinct neighborhoods:

1. Orchard, a predominantly single family/duplex neighborhood within the city limits to the east and along the southern site boundaries.
2. County, on the western boundary across the city line, where some residential dwellings on large rural lots still occupy most of the area adjacent to the landfill.
3. Fircrest, a middle to upper middle income town of single family homes along the northwestern site boundary.

Incinerator. The Marion County incinerator is located about seven miles north of Salem, OR, close to Interstate I-5, in the village of Brooks. The mass burning grate incinerator began operation in 1986 and accepted about 135,000 tonnes per annum of municipal waste from Marion County, 70% of which is generated by the City of Salem. Recently, Marion County and the operators were granted a permit to burn 171,000 tonnes per annum. The incinerator is equipped with a quasi-dry chemical scrubber and baghouse filters.

Brooks, the host community, is an unincorporated farm village of about 300 residents. It serves as a service center for the farms and rural residences in the area. The village itself comprises a church, retirement village, mobile home parks, some older shacks, post office, fire department, hardware and farm stores and some onion warehouses along the railroad tracks. Outside the village, the area comprises rural residential homes and small clusters of houses and farms.

Data collection

Physical impact data and residential property characteristics and prices were compiled for the two sites (see table 1). A list of potential physical emissions was derived from literature research (Zeiss, 1984a, b) and personal observation. The measurement methods were selected to closely reflect residents' perception of facility impacts; measurement conditions were selected to represent common worst-case conditions. The physical impacts were then plotted as facility "footprints" for landfill and incinerator (Figures 1a and 1b, Zeiss, 1988).

At the landfill, leachate and gas emissions cause slight health risks with some corollary groundwater and air quality deterioration up to 1,000 metres (0.65 miles) from the site. Odor, noise and view nuisances were detected within 200 to 300 metres (660 to 985 feet) of the landfill boundary.

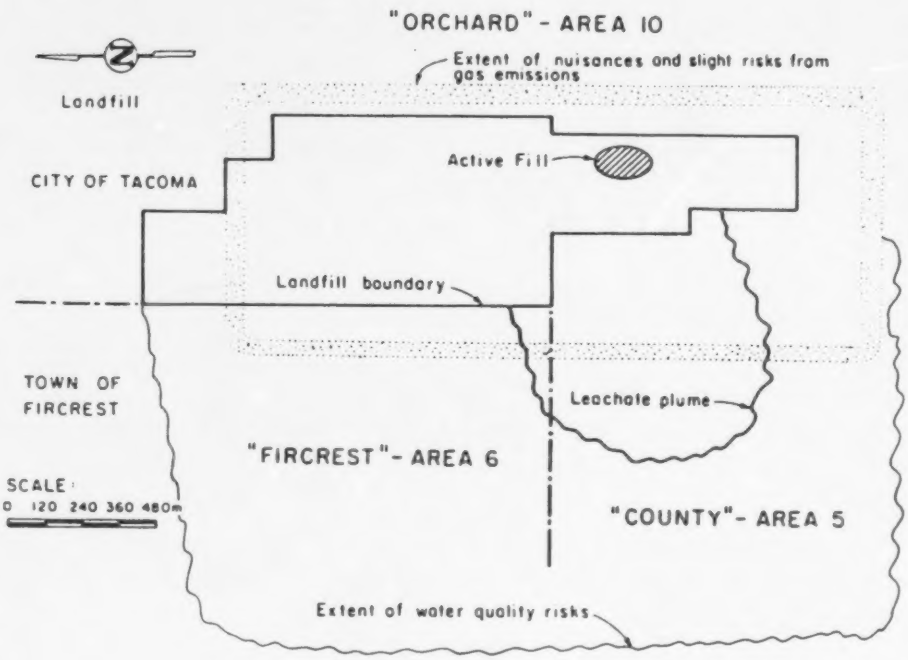
"ORCHARD" - AREA 10
Z
Landfill
Extent of nuisances and slight risks from gas emissions
CITY OF TACOMA
Active Fill
Landfill boundary
TOWN OF FIRCREST
Leachate plume
"FIRCREST" - AREA 6
SCALE:
0 120 240 360 480m
"COUNTY" - AREA 5
Extent of water quality risks

FIG. 1(a).—LANDFILL PHYSICAL IMPAJCT

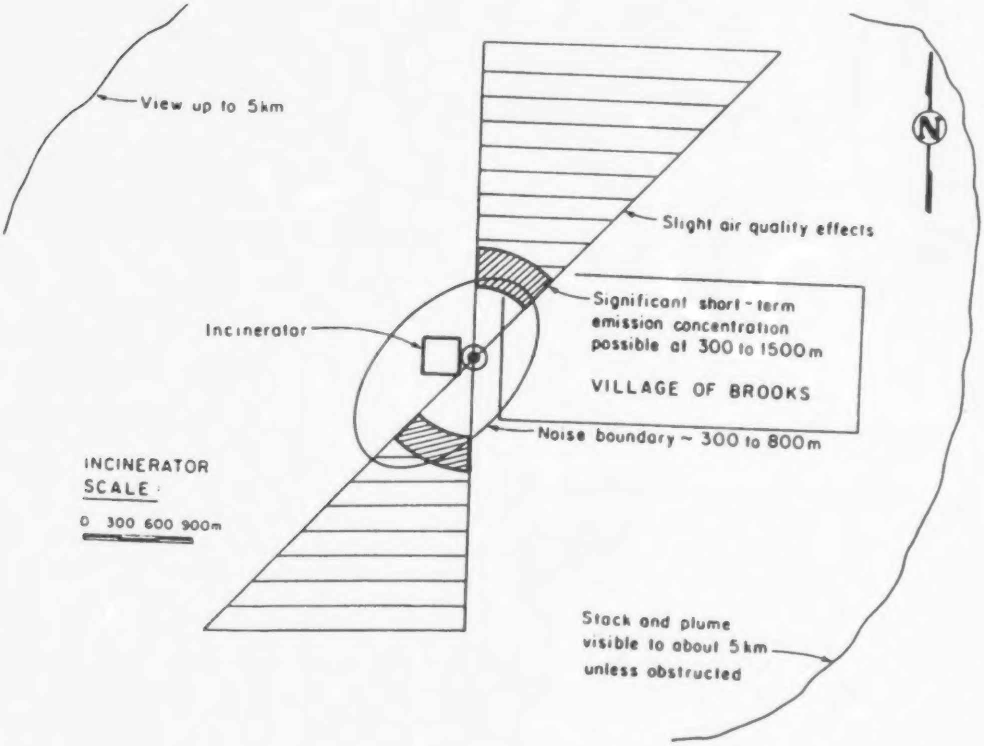
View up to 5km
N
Slight air quality effects
Significant short-term emission concentration possible at 300 to 1500m
Incinerator
VILLAGE OF BROOKS
Noise boundary ~ 300 to 800m
INCINERATOR SCALE:
0 300 600 900m
Stack and plume visible to about 5km unless obstructed

FIG. 1(b).—INCINERATOR PHYSICAL IMPACT FOOTPRINT

The incinerator generates slight air quality deterioration within 300 to 1,500 metres (985 to 4,920 feet) from the site in prevailing wind directions with a slight chance of significant quality impacts at 700 to 800 metres (2,300 to 2,625 feet). View of stack and steam plume extends up to 5 kilometres (3 miles) from the site, while noise recognition extends to 600 to 800 metres (1970 to 2,625 feet) from the site.

Both facilities have some obvious nuisance impacts and slight air and/or water quality impacts. At the landfill, slight health risks are possible for lifetime exposure.

Property characteristics and sales prices (see table 1) were compiled and coded for each of the total 665 residential property sales between 1983 and 1986 in the landfill host community (Tacoma-Pierce County Board of Realtors, 1986). At the incinerator site sales data for 145 residential property listings between 1982 and 1987 were compiled (Salem Multiple Listings Bureau, 1982-1987). The exposure to facility's physical impacts was coded for each property according to the facility footprints (figures 1a and 1b).

TABLE 1.—MULTIPLE REGRESSION ANALYSIS OF FACILITY IMPACTS ON PROPERTY VALUES IN HOST COMMUNITIES - VARIABLES

Dependent variables (1)	Independent variables (2)
Sales price	Property characteristics Number of bedrooms Age Floor space Condition Amenities - Fireplace - Basement - Garage Lot Size
	Facility Impacts Distance View Odor Noise Air quality Water quality Accident risk

The null hypothesis in this test states that the exposure to facility impacts does not explain variation (and differences) in property sales prices. Thus, for the null hypothesis to be rejected at least one indicator of facility impact must be shown to significantly explain variation in property prices.

Multiple regression analyses were run on the UBC-SPSSX program with stepwise selection of independent variables. The assumptions were checked and were met moderately to fairly well for most variables. No data transformations were done.

Results

Landfill. The three areas in Tacoma near the landfill (Orchard - Area No. 10, Fircrest - Area No. 6 and County - Area No. 5, Tacoma Real Estate Research Committee, Fall, 1986) are treated as separate neighborhoods throughout the analysis because of their distinctly different ages and characters.

The sales price is regressed on year and quarter of listing as well as eight housing characteristics and eight physical impact variables. Table 2 lists first, the multiple regression coefficient (R^2) and then the significant independent variables and their partial correlation coefficients by neighborhood area.

All three multiple regression equations are highly significant and generate significant explanation of sales price variation with R-squared values between 0.73 and 0.77. Only in the Orchard area are any facility impacts (explosion risk and air quality) significant in explaining price variation, but their signs are positive and thus contradict the expected negative effect of such facility impacts on price. Closer scrutiny revealed that about 15 newer homes were recently built within the explosion risk and air quality impact areas (on the south west corner of the landfill). These houses sell at $55,000 to $60,000, which is substantially higher than the average price of $42,920 for area 10. This new development is therefore likely to cause the spurious effect of explosion risk and air quality on sales price in the analysis. Since no facility impacts are significant in either of the other areas 5 and 6, the landfill does not appear to affect property values in the host community.

Incinerator. The multiple regression of price on property characteristics and incinerator impacts was calculated for three periods of the siting process:

- 1983 to 1987 to include both siting and operational phases together
- 1983 and 1984 to cover the siting process before any construction or physical impacts had occurred, and
- 1985 to 1987 to cover the construction and operation phase separately.

The results are listed below for the three time periods in table 3.

Explanatory power of sales prices is good with R-squared values at 0.44 to 0.54. However, none of the facility impact variables is significant in explaining variation in prices during any of the three siting phases. Thus, subject to the assumptions of the model, an influence of the incinerator on residential property values cannot be confirmed.

Summary of Property Value Studies

The detailed analysis at two typical waste facility sites shows no correlation of observed physical facility impacts with residential property values in host communities. This lack of effect corroborates the results reported in the literature. Thus, both sets of findings corroborate each other and indicate that waste facilities have inconsistent or insignificant effects on residential property values. The lack of property value impacts contradicts strongly held beliefs about waste facility impacts on property values, despite the presence of verified physical impacts and the use of a properly specified model.

TABLE 2.—TACOMA LANDFILL - HOST COMMUNITY RESIDENTIAL REAL ESTATE SEALES, 1983-1984, MULTIPLE REGRESSION ANALYSIS RESULTS

Dependent variable (1)	Significant independent variables (2)	Sign of partial correlation coefficient (3)
Area 5 County - Number of cases = 136		
Sales price R² = 0.74 significant	Square feet	
	Age	–
	Basement	–
	Quarter of sale	–
	Condition	–
Area 6 - Fircrest - Number of cases = 179		
Sales price R² = 0.73 significant	Square feet	
	Age	–
	Lot size	+
	Quarter of sale	+
	Condition	+
Area 10 - Orchard - Number of cases = 348		
Sales price R² = 0.77 significant	Condition	+
	Square feet	+
	Age	–
	Fireplace	+
	Number of bedrooms	+
	Explosion risk	+
	Garage	+
	Air quality impact	+

Results: No facility impacts with correct signs significantly explain variation in sales prices.

TABLE 3—SALEM INCINERATOR - HOST COMMUNITY RESIDENTIAL REAL ESTATE SALES, 1983-1982, MULTIPLE REGRESSION ANALYSIS RESULTS

Dependent variable (1)	Significant independent variables (2)	Sign of partial correlation coefficient (3)
Period: Siting to present, 2nd quarter 1983 to 1st quarter 1987 Number of cases = 89		
Sales price R² = 0.44 significant	Square feet	+
	Lot size	+
	Number of bedrooms	+
Period: Construction and operation to present, 1st quarter 1985 to 1st quarter 1987 - Number of cases = 25		
Sales price R² = 0.54 significant	Lot size	+
	Age	–
Period: Siting, 2nd quarter 1983 to 4th quarter 1984 - Number of cases = 61		
Sales price R² = 0.52 significant	Square feet	+
	Lot size	+
	Number of bedrooms	+
	List date	+

Results: No facility impacts significantly explain variation in sales.

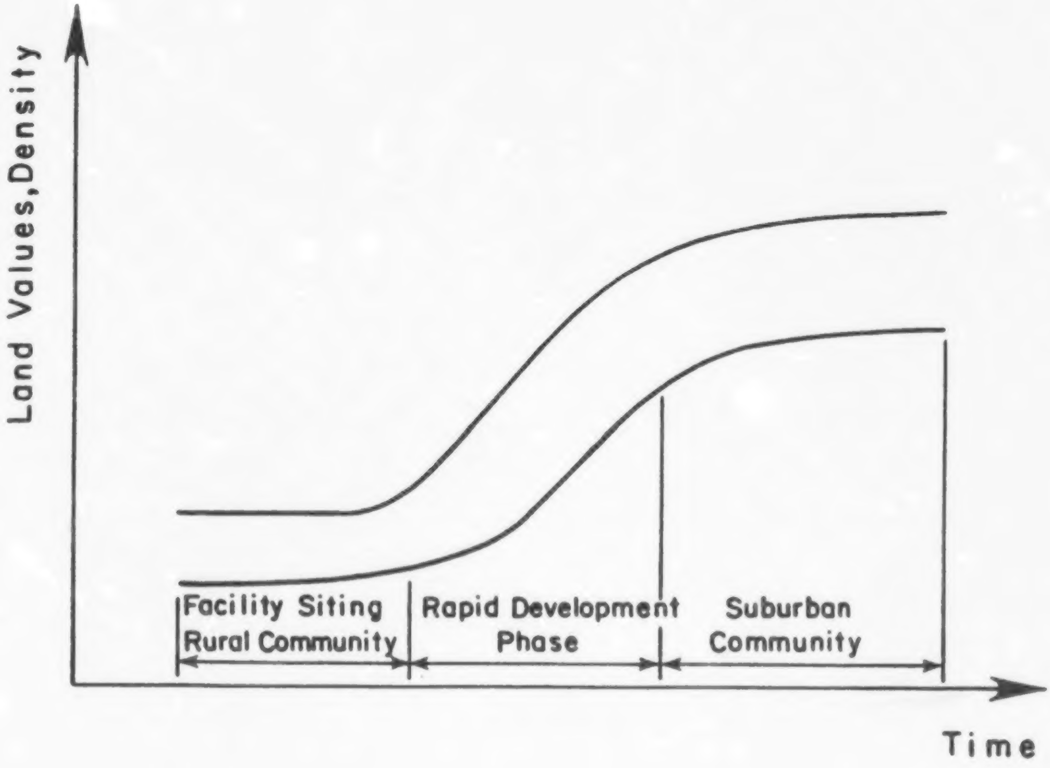

FIG. 2—FACILITY SITING AND SUBSEQUENT DEVELOPMENT IN A TYPICAL HOST COMMUNITY

PROPERTY VALUE GUARANTEES TO ADDRESS RESIDENTS' FEARS

Property value guarantees may, however, still be an effective tool in addressing residents' fears about facility impacts. If residents believe that a waste facility may cause property value impacts, then guaranteeing to affected residents the fair market value "as if the facility were not in existence" (Wisconsin Facility Siting Board, 1987) may enhance acceptance. The issues to be tested here are therefore the following:

a) Do residents believe that waste facilities cause significant effects on property values?

b) Do property value guarantees make the facility more acceptable to host community residents?

Definition and Theory of Property Value Guarantees

Property value guarantees (PVG) are a form of compensation for losses in market sales price of residential property near waste disposal and other undesirable facilities (Wisconsin Facility Siting Board, 1987, and City of Seattle, 1986). Usually, PVG provide property owners with the hypothetical fair market value of their properties without the influence of the facility. This hypothetical fair market value is established by up to three independent appraisals. The facility proponent guarantees property values by either paying the owner the difference between sales price and hypothetical fair market value if the sales price is lower, or by buying the property outright if no reasonable offer is received within a defined time period (usually three to nine months). PVG are usually extended to all existing property owners in a defined area around the facility site at the time of site selection. Subsequent owners and additional parcels resulting from subdivision after site announcement are thus excluded. Provisions are made to ensure arm's-length sales prices.

Property value guarantees may be an effective tool in facility siting because they address a major concern before the facility is built, regardless if property value losses actually occur or can be verified. If the theory corresponds with residents' perceptions, then PVG are a simple, market-price based method to compensate property owners for a variety of physical and intangible waste facility impacts with the goal of gaining host community acceptance.

PVG, in theory, prevent any market value losses to existing owners at the time of site selection. They do not, however, cover any special or sentimental value to the present owners (Knetsch, 1983), nor are the costs included to search and move to a new home. Finally, PVG address losses only to those residents who actually sell and move. Residents who decide to stay and put up with the facility are not compensated for their losses by PVG. For long term residents who are well attached to their community the facility impacts may constitute a substantial loss without, however, causing them to move. Thus, PVG do not cover all losses.

Methodology

Residents' concerns and attitudes were obtained with a survey in host and control communities at both landfill and incinerator study sites. Approximately 50 respondents in each host community were selected by systematic random sampling from a list of all street addresses (Polk Directories for Tacoma, WA and Salem, OR, 1986) within 2 kilometres (1-1/4 miles) of the landfill and 3 kilometres (1.9 miles) of the incinerator site boundaries. Approximately 50 control respondents were selected at each site by random sample of addresses from telephone books after eliminating inner city addresses. In this way, the control groups comprise residents of communities comparable to typical host communities on or outside the urban growth boundary.

A written survey form was sent to each respondent with a pen and a self-addressed envelope. The obtained response rates were between 50 and 60%, with slightly higher rates among the host groups than among controls.

Results

Beliefs about Negative Impacts from Waste Facilities. Host community respondents were asked to state their agreement or disagreement with statements about possible facility impacts on the host community. A significant proportion of respondents believes that the facility causes a variety of physical and non-physical impacts in the host community (see table 4). Property value impacts are perceived to occur at both sites. Furthermore, physical (nuisances, health risks and environmental change), social (community image), and political impacts (loss of control, unfairness) are significantly mentioned at both sites.

TABLE 4.—NEGATIVE BELIEFS ABOUT IMPACTS AND CORRELATION OF NEGATIVE BELIEFS WITH ATTITUDE ABOUT THE FACILITY

Facility impacts (1)	Proportion of respondents with negative Beliefs (2)	Ranking of strength of correlation of belief with attitude about facility (3)
	Landfill	
Nuisances	66%	2
Health risks	45%	3
Property values	41%	4
Community image	41%	1
	Incinerator	
Nuisances	41%	4
Property values	38%	2
Community image	41%	3
Community control	42%	1
Fairness	44%	5

Property Value Guarantees and Facility Acceptance

In a scenario put to all respondents in host and control communities, the waste facility is identified as the cause of an intolerable situation in the community. The owner/operator offers to compensate for property value losses if the residents decide to move. Respondents are asked to state whether they consider the offer very unfair, somewhat unfair, acceptable or completely fair.

Because the samples are relatively small, the answers are combined and presented as proportions of host and control respondents at both sites who consider PVG to be "fair" (i.e. acceptable or completely fair) or "unfair" (i.e. somewhat unfair or very unfair, see table 5).

TABLE 5.—FAIRNESS OF PROPERTY VALUE GUARANTEES

Scenario: Assume the situation in your neighbourhood becomes intolerable because of the waste facility's impacts. The owner/operator offers to compensate you for any property value losses you may experience in selling your home.

Question: Do you consider this offer to be (please mark one):

RESULTS

Community (1)	FAIR (2)	UNFAIR (3)	Difference of proportions (4)
Landfill			
Host N=34	44.8%	55.2%	Not significant
Control N=26	46.1%	53.9%	Not significant
Incinerator			
Host N=33	51.5%	48.5%	Not significant
Control N=25	41.0%	59.0%	Not significant

The results indicate that property value guarantees will achieve approximately 50% voluntary acceptance of a facility. Since 50% acceptance leaves an equal fraction of opposing residents, the corollary issue is to determine whether PVG actually sway to acceptance those residents most likely to oppose it. Therefore, additional analyses were conducted to test the effect of property value guarantees on people who are annoyed or hold negative beliefs about the facility's impacts. The responses on beliefs about significant facility impacts were cross-tabulated with the opinions on fairness of property value guarantees (see table 6). If property value guarantess are effective in gaining acceptance, they should be considered a fair offer by those correspondents who initially hold negative beliefs about the facility's impacts.

At the Tacoma landfill there appears no significant association between perceived impacts and opinion on property value guarantees. This is probably because the facility has been located in the neighborhood for 25 years. In this time, most residents have moved into the neighbourhood with some awareness of the situation in the community with the landfill and do not experience the impacts as distinct losses.

At the newer incinerator site, however, the cross-tabulation of negative impact beliefs with opinion of property value guarantees shows a clear and statistically significant pattern (see table 6). Respondents in the host community who are more annoyed with the incinerator and who believe the facility causes health risks, depresses property values, harms the community image, or decreases confidence in the local government consider compensation through property value guarantees significantly less acceptable than other residents. This means that property value guarantees do not make this new incinerator more acceptable to those who are most opposed. Even people who believe the facility affects property values (among other things) do not consider PVG fair compensation. Therefore, alternative approaches would seem necessary.

TABLE 6.—EFFECTS OF PROPERTY VALUE GUARANTEES ON ACCEPTANCE OF FACILITY IMPACTS AT A NEW INCINERATOR

Questions (1)	(2)	Proportion of respondents who consider property value guarantees - Sample N = 33		Chi Square Test Statistic (5)
		FAIR (3)	UNFAIR (4)	
Are you annoyed with the facility?	Yes	35.3%	64.7%	
	No	68.8%	31.3%	Significant
Do you believe the facility affects:				
property values?	Yes	38.5%	61.5%	
	No	85.7%	14.3%	Significant
community image?	Yes	31.3%	68.8%	
	No	64.3%	35.7%	Significant
health risks?	Yes	12.5%	87.5%	
	No	60.0%	40.0%	Significant
confidence in local government:	Yes	11.1%	88.9%	
	No	66.7%	33.3%	Significant

Alternative Approach to Gaining Host Community Acceptance

A different perspective on the problem of waste facility impacts can be gained by identifying the steps of cause-effect connections from waste generators to waste disposal facility impacts on the host community. This perspective is developed by defining and analyzing a typical waste disposal system for a large urban center (see figure 3).

Within this system, there are four methods to address facility impacts:

- Prevention is defined as a measure that reduces the cause of impacts prior to the source, i.e. before the siting process begins or before the waste stream reaches the facility.
- Control measures focus on impact reduction within the subsystem boundary of the waste facility or during the siting process.
- Mitigation comprises all measures to reduce impacts downstream from the facility and after the facility is built. Basically this category includes measures outside the compliance boundary, i.e. those which reduce impacts at the receptor rather than at the source.
- Compensation measures are alternative benefits that are offered instead of impact reduction. Compensation can be in kind, e.g. as the provision of an alternative water source for contaminated groundwater, or as an alternate good, e.g. as money.

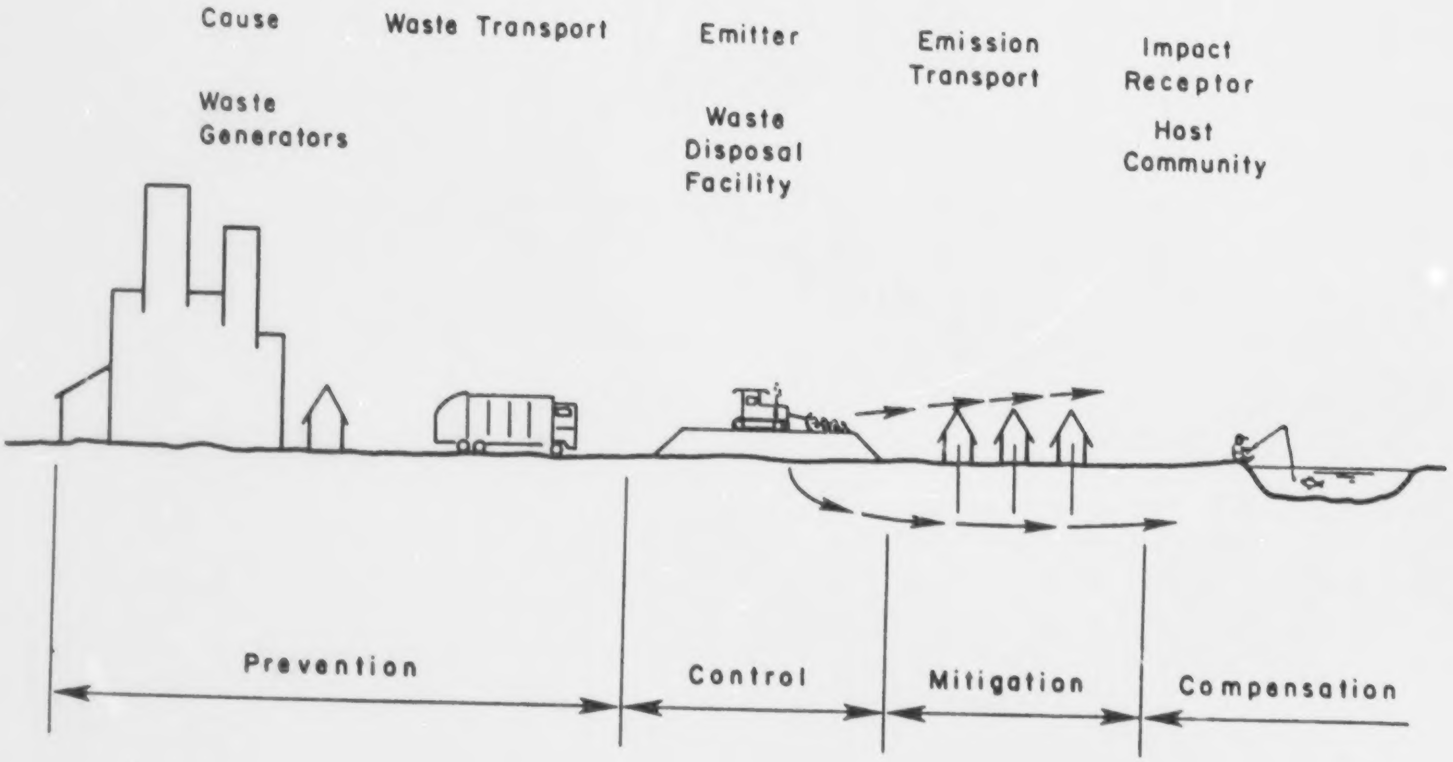
Cause
Waste Generators
Waste Transport
Emitter
Waste Disposal Facility
Emission Transport
Impact Receptor
Host Community
Prevention
Control
Mitigation
Compensation

FIG. 3.—WASTE DISPOSAL SYTSTEM AND IMPACT REDUCTION METHODS

Property value guarantees summarily address the resulting impacts by reducing the monetary losses at the tail end of the cause-effect chain, i.e., after the impacts have occurred. In contrast, impact prevention, control and mitigation measures (see figure 3) reduce impacts in kind rather than eliminate money losses.

Because property value guarantees do not address the primary impacts (health risks, image impacts, loss of control and confidence) per se, but, rather, reduce consequential losses to property values, they do not address the initial cause or source of the impacts. This lack of remedy for the original cause or source may be the reason why property value guarantees do not effectively address host community concerns.

An alternative approach to acceptance is to identify specific impacts and reduce them as close to the source (i.e., the waste generating center) as possible, for example, though prevention (waste separation), technical control of emissions at the facility, and impact mitigation. This approach is being developed and tested in current research and will be reported in the near future.

ACKNOWLEDGEMENTS

This research was made possible by a graduate fellowship from the Canadian Mortgage and Housing Corporation (CMHC) and an operating grant from the Canadian Natural Sciences and Engineering Research Council (NSERC). This support is gratefully acknowledged.

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A CANDID VIEW FROM THE FRONT LINE

Pollution Probe

Colin Issaacs

Paper unavailable at time of printing

PUBLIC CREDIBILITY AND MONITORING REAL WORLD TRENDS

Tricil Ltd.

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MEDIA RELATIONS AND CRISIS MANAGEMENT

Tom Donoghue , APR
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Calgary, Alberta

THE PLAYERS

When a spill, leak, emission, explosion or accident occurs in the waste management industry, the last thing managers want to see is the news media. The news media are a threat, a problem, a nuisance to be avoided at all costs. Media relations specialists classify this mental disorder as suicidal.

There are three primary players in a crisis situation: the company involved in the situation, the news media and the public. It is the company's job to gain control over the crisis as quickly as possible in the interests of public health and safety. It is the news media's job to learn the facts as quickly as possible and report to the public. It is the public which is concerned if health and safety are at risk.

The public relies on the company and the news media to tell the truth. Thus, the company and the news media often find themselves co-operating to fully inform the public,

It's Their Job. Co-operating with pushy journalists may seem frivolous to management trying to control a crisis, but journalists have a necessary and legitimate role to play. It is their job to get to the scene quickly. It is their job to ask probing questions. It is their job to get photographs and video where possible. It is also their job to meet deadlines.

Journalists are highly competitive and will often arrive at the scene before emergency crews. It is vital that management understand the needs of the media and that journalists be treated with professional respect.

If management wont talk to reporters, the reporters will find someone who will. If reporters can't get answers to their questions, they will find answers elsewhere. If the answers aren't known at the time, say so, and say what you are doing to find out. Companies which fail to address the news media's needs, which fail to speak openly and honestly play Russian Roulette with six loaded chambers.

The key to working with reporters in a crisis situation is to be prepared. Enlightened companies have a Media Relations Plan incorporated into their Emergency Plans. They recognize that how reporters are treated during a crisis can directly effect the quality of the coverage. Minor events are often blown out of proportion because management hides from the media or mistreats the media. The resulting information vacuum is filled by rumor, fear, misinformation and innuendo. While the reality of the event may be minor, the perception can quickly become one of catastrophe.

Making It Work. Successful media relations in a crisis situation starts by consulting with the company's public relations personnel, or hiring outside professionals. Like the waste management industry, media relations is no place for amateurs. Success is a combination of solid planning, rehearsal, preparation and a little luck. The basic approach can be outlined as follows;

Before the Crisis.

1. Incorporate a Media Relations Plan into the Emergency Plan
2. Rehearse the Media Relations Plan along with the Emergency Plan
3. Select a spokesperson (only one) to do the talking
4. Secure top quality media training for the spokesperson
5. Develop an understanding of the news media, how they work and what they need

During the Crisis.

1. Treat all reporters with respect
2. Be aware and sensitive to their deadlines
3. Ensure the spokesperson is accessible and available
4. Be open, honest and candid at all times
5. Monitor the coverage as the crisis unfolds

After the Crisis.

1. Analyse the media coverage
2. Analyse how the Media Relations Plan succeeded and/or failed
3. Correct faults in the Media Relations Plan
4. Follow-up with reporters who covered the story
5. Learn from the mistakes
6. Have a stiff drink

THE SOCIAL ASPECTS OF DEVISING AN IMPACT MANAGEMENT PROGRAM

10th Canadian Waste Management Conference
25 -27 October, 1988, Winnipeg, Manitoba

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INTRODUCTION

If there is one thing that can be said about the environmental assessment process and the high degree of public controversy that often accompanies the review of facility proposals, it is that the process has stimulated a lot of innovation in planning and policy processes, especially with respect to public involvement provisions. Current approaches to impact management provide ample evidence of this. Not only has the scope of proposed impact management measures broadened considerably, but so has the role of potentially affected publics in determining what should be done to deal with potential impacts. It goes without saying that these changes are placing new demands on facility proponents and government regulators.

IMPACT MANAGEMENT

The purpose of impact management is to eliminate, reduce or offset real or perceived adverse impacts associated with the siting, construction and operation of a facility. Generally, impact management measures can be grouped into four broad categories (Armour, 1987):

mitigation measures which aim to avoid or reduce potential negative effects; such measures can be applied on-site and/or off-site and commonly include modifications to facility design (e.g., installation of pollution control devices or noise baffles), careful site design (e.g., putting berms or barriers in appropriate locations to minimize noise or visual intrusion, landscaping unsightly areas), adoption of environmentally sound construction and operational practices (e.g., stockpiling excavated soil well away from stream banks, applying dust suppressants in construction areas), retrofitting nearby residences (e.g., installation of air conditioners or additional glazing to reduce noise impacts, planting trees and shrubs on properties impacted by visual intrusion), and local service or facility improvements (e.g., upgrading local roads to minimize safety hazards).

contingency measures which aim to aid in the detection and timely response to potential problems and unanticipated effects; a sound contingency program generally includes monitoring provisions, emergency response planning, alternative dispute/claims resolutions procedures, and setting up of a fund to cover potential environmental liabilities.

compensation measures which aim to reduce or offset unavoidable negative effects; these can be either impact-related (intended to leave the community no worse off than they were before the facility was constructed) and/or equity-related (intended to leave the community better off than they were before the facility was sited); currently the range of measures include in-kind compensation (i.e., replacement of what is lost), service subsidies (to support the expansion of services that may be required to offset the effect of increased demand), property tax abatement (to offset any potential increase in property taxes), property value protection (guarantee of payment of fair market value as protection against a real decline in property value due to construction and operational impacts), off-site property buy out (for those residents who are likely to suffer significant levels of unavoidable impacts for extended periods of time), local purchasing and hiring policies, tax subsidies (e.g., payment of all or part of the property taxes of residents), tipping fees, co-use of the facility, bonus services (e.g., the provision of infrastructure such as schools, hospitals or other amenities which would enhance the community's development potential), and bonus facilities (e.g., construction of a research or educational centre).

community relations measures which aim to ensure effective, on-going two-way communication and joint problem-solving; these can include establishing a community monitoring committee, providing funds for community-hired independent experts, establishing a community liaison committee, setting up a hotline, establishing a complaints procedure, and making use of third-parties to facilitate the resolution issues.

Mitigation has been a standard component of project planning and environmental assessment processes from the start and is relatively well developed. It is the other three categories, in particular compensation and community relations, which are now beginning to attract attention. It is not hard to explain why. Recent social science research findings suggest that a comprehensive approach to impact management, one that goes beyond mitigation, has the potential to make the siting waste management and other unwanted facilities less conflict-ridden and controversial. For example, Swartzman et al (1985), determined that offering compensation (such as property tax reductions and payment of a user fee to the community) and risk reduction inducements (such as increased monitoring frequency and increased control over who monitors), can help reduce public opposition to hazardous waste landfills. Similarly, Schuff (1988) notes that compensation has played a key role in the siting of waste management facilities in Wisconsin. And studies by Paige and Owens (1984) and Visocki (1988) revealed that the provision of additional economic benefits and careful designed community relations initiatives have been key determinants of successful waste management facility siting efforts in Europe.

Needless to say, resolving the facility siting problem is not as easy as these research findings might suggest. Devising an effective impact management strategy is far from a simple matter. And, if approached in the wrong way, it can easily backfire. Thus, it is important to proceed carefully.

DEVISING AN IMPACT MANAGEMENT STRATEGY

There are many considerations to take into account when developing impact management policies and programs. Attention will be directed here to the social as opposed to the legal, economic, and engineering aspects of the task.

Three principles should guide the development of an impact management program.

1. The measures should be "socially responsive".

A sound understanding of the public's concerns is an obvious prerequisite to the development of sound impact management strategies. This involves more than determining what impacts and risks are of most concern to those who will be potentially affected by a proposed undertaking. Such information should be, by now, standard features of environmental and social impact assessment documentation. Rather, it involves a sensitive probing of the public's "other agenda".

Research into facility siting disputes clearly shows that community opposition usually extends well beyond the matter of impacts and risks per se into such issues as perceived inequities in the distribution of costs and benefits, the stigma associated with certain facilities, the stigma associated with being "the loser" in the siting process, feelings of loss of control over the forces affecting the quality of one's life and community, and distrust of proponents and government regulators (Krawetz, 1979; U.S. Environmental Protection Agency, 1979; Armour, 1983; Elliott, 1983). Often, such concerns are rooted in past negative experiences with the siting and/or operation of similar facilities in the community and with the actions of facility proponents and/or government regulators (Armour and Institute of Environmental Research, 1987).

The tendency has been to discount this agenda by either putting it down to no more than the kind of "sound and fury" one can expect from opponents nowadays or by labelling it as something to be dealt with sometime, somewhere in "the political process". The result needs little elaboration. Study after study has shown that failure to acknowledge the legitimacy of this agenda and to take such issues and experience into account in the siting process in no small way accounts for the current facility siting dilemma (Krawetz, 1979; U.S. Department of Energy, 1986, Armour, May 1987; Kraft and Clary, 1988).

2. The measures should be "situationally appropriate".

It is not difficult to generate a list of impact management measures for each of the four categories listed above. There have been several recent surveys of impact management practice, especially with respect to the use of compensation and other incentives, that can serve as guides. What is evident from current experience, however, is that impact management programs must be tailor-made to suit the socio-political context in which they are applied. They must be project- and community-specific.

Determining what kinds of impact management measures are most appropriate for a given situation and devising a specific program involves (a) identifying the kinds of impacts and social issues that are of concern; (b) evaluating the effectiveness of possible measures given the project and community context in which they will be applied; (c) assessing the responsiveness of proposed measures to community concerns; (d) identifying the kinds of commitments that will be required to implement the measures; and (e) identifying any constraints that could affect implementation.

3. The measures should be "jointly designed".

If an impact management program is to respond effectively to the concerns and needs of those who are likely to be impacted, then it must be developed in consultation with them. In essence, devising a socially responsive, situationally appropriate impact management program can only be done through a process of collaborative problem-solving that leads, hopefully, to "win-win" negotiated agreements.

Unfortunately, current approaches to project planning, site screening and environmental assessment tend to foster "us-them" adversarial relations and thus are not very conducive to the achievement of this objective. The way the siting process now works, impact management is addressed quite late and when relationships among proponents, publics and regulators are invariably strained. At that point in time, proposals for monitoring, compensation and two-way communication are likely to be seen as not so subtle forms of manipulation or bribery or, alternatively, as an opportunity to dig deep into the pockets of proponents.

There are two ways to prevent such outcomes. First, there should be an up-front commitment, at the start of the facility siting process, to a comprehensive impact management program. Such a commitment would prevent impact management proposals from being seen as a last ditch attempt to win over affected publics. There is sufficient experience with impact management to enable a broad policy framework to be put forward well in advance of technology and site-specific assessments. And second, more effort should be directed towards encouraging collaborative problem-solving and joint decision-making throughout the siting process, not just when it gets down to devising specific impact management proposals.

FROM PUBLIC ACCEPTANCE TO SOCIAL CONSENSUS

The development of socially responsive, situationally appropriate and jointly designed impact management programs is coming to be seen as a critical component of facility siting. But it is certainly not a panacea. And, more importantly, if approached inappropriately, impact management has the potential to make current facility siting problems worse.

A fundamental problem is that, at this point in time, the name of the game in facility siting has become "gaining public acceptance". What is implied by this is the need to persuade, convince or somehow turn around the opinions of concerned publics. Impact management, seen through this worldview, has the potential to devolve into nothing more than a bargaining tool in a process where, to put it crassly, the concern is simply "what's your price?" The negative implications of this are obvious and cannot be ignored. It would be far different if the game was approached as one of "achieving social consensus" and effort was directed towards working "with" rather than, as is so often the case, "against" or "in spite of" concerned publics. In this mind set, the potential for impact management to evolve as a positive, problem-solving force is far greater.

The problems that plague facility siting processes go deep and it is going to take much more than elaborate impact management programs to turn things around. When all is said and done, the potential effectiveness of impact management or any strategy for resolving facility siting conflicts is basically dependent on the overall perspective that is brought to the siting process and the role of affected publics in it. And in this regard, basic premises clearly warrant rethinking. Labelling the public's response to facility siting proposals as

NIMBYism or putting it down to irrational fear puts all of the "blame" for current siting problems on the public. However, this pushing of the problem off onto "the public" is simply an easy way to abdicate responsibility. And it not only leads to inappropriate responses, such as focussing on "gaining public acceptance", but it can be needlessly self-defeating. Turned around into an "us" instead of just a "them" problem, the facility siting and waste management problem takes on new dimensions and opens up important opportunities for more effective action. The three principles of impact management presented above provide one indication of kind of changes that are needed.

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